SCIENTIFIC AMERICAN

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SCIENTIFIC AMERICAN

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THE STEAM-SHIP GREAT BRITAIN.

SCIENTIFIC.

First Principles of Mechanics.

CHEMISTRY.

NEW INVENTIONS.

SMITH'S ELECTRO-MAGNETIC MACHINE.

FACSIMILES OF THE FIRST ISSUES OF THE SCIENTIFIC AMERICAN

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THE EFFECT OF INVENTIONS ON THE PEOPLE'S LIFE.

The material world has advanced so rapidly during the last half century, and with a pace so accelerated, that mankind has almost lost one of its most important faculties, and one essential to happiness—that of surprise. The nil admirari faculty is attaining a wide spread. The most marvelous developments are taken as a matter of course—the condition of things fifty years ago is seldom pictured to the mind—and all the material blessings which we now enjoy are used as conveniences of daily life, and no more. Formerly there was an idea prevalent that surprise and astonishment were emotions of the ignorant. To-day they are rather emotions of the scientist. The educated engineer cannot without such emotions contemplate the insignificant feed wire of a trolley road carrying silently hundreds of horse power to points all along the line—he cannot without these feelings contemplate the electric motors, drawing power in proportion to the work they have to do, all regulated by the automatic government of counter-electromotive force—he cannot see the unstable though gigantic ocean liner filled with every refinement of electrical and mechanical art, all working perfectly on their never quiet, never level platforms—he cannot follow the construction of a cantilever bridge with the ensuing changes from compressive to tensile stress and the reverse, as the span is completed—these things all excite in him such emotions that he cannot observe them and know them without a feeling of true astonishment at the achievements of mankind.

Our other columns at once, in their fullness and necessary and inevitable inadequacy, bear testimony to the status of our age. They are filled with most interesting matter from the pens of specialists. Yet in spite of the special competency of their authors, all acknowledged authorities—notwithstanding the pages of matter and quantities of illustrations—we feel that the task of telling about the progress of a lifetime can at the least be only inadequately performed—so much has been done.

The temptation is to consider the greater things, to contemplate the 600 foot steamer crossing the Atlantic through storm and sunshine—the open hearth furnace with its tons of steel, fluid as water and resembling molten silver—the immense steam engine and great hydraulic power plant. But we may usefully leave for the moment the monumental works of the last half century and see what changes have been effected in our daily life by the movement of progress.

The steam engine has been greatly improved, and in the articles on naval progress and the locomotive much will be found on its development. The Corliss valve motion and the compounding of cylinders, leading to more perfect expansion and a longer range of working temperature limits, have brought about great economy so that one-tenth the fuel will do the same work as compared with many engines of the middle of the century. In details, such as the supply of water to the boilers by injectors and inspirators, doing away with the feed pump, the machine stoker for supplying fuel, and the feeding of oil drop by drop to the cylinder, the drops passing through a glass tube so as to give sight feed lubrication, the steam power plant has had many and great developments.

The machine shop has not been neglected, and America can boast of the finest machine tools, for wood and metal, such as automatic lathes, milling machines and shapers, that the world can show. The development of abrasives, emery and carborundum, has made the emery grinder a necessary tool in every machine shop. The miner even shares in the advance, special machinery for extraction of ore, for undercutting and drilling being invented, while modern explosives of graduated power and quickness make the work of placing shots much safer. Compressed air has been used in some classes of underground work, but electricity is making its presence felt there also, and electric machinery for tunneling and mining is in extensive use.

The work of St. Clair Deville in the days of the last Napoleon have borne fruit, and now aluminum has a recognized place among commercial metals. In its reduction the electric furnace and the electrolysis of fused salts have been tried, and the cheapened production of sodium has had its effect on the cost of production.

The lightness of the metal led to hopes that it might lead to the construction of a flying machine. The development of the laws of moving aeroplanes have given a better basis perhaps in this direction than any preceding work, and the theory of the internal energy of the atmosphere gives a possibility of the solution of the problem of soaring flight. Yet very little has been really accomplished, although more has been done during the last five years to raise the rational hopes for true mechanical flight than during the fifty years that preceded.

Food for the family is now procurable in endless variety, independent of the season of the year. The enormous development of the canned goods industry, of cold storage and of cheap transportation makes the salmon of Oregon, the delicate fruits of California, and the vegetables of the West familiar to the residents of the most distant cities. The winter kitchen can have every summer vegetable, and the feats of the Romans in supplying the tables of its emperors are daily surpassed, only it is now done for the benefit of the poor. Even in the treatment of food, notably of the cereals, there is great advancement, and the roller mill turns out flour of greatly improved quality, and with larger yield from the grain than was done by the old grist mills.

In the matter of the transportation of water the most impressive achievements of engineering are executed in order that at the turning of a kitchen faucet water may flow into the kettle of the cook. The contrast between old and new methods is nowhere more forcibly presented than in the two Croton aqueducts—one of the year 1842, following approximately a contour line from the Croton Lake to the Central Park, New York, its path being traceable from the surface over nearly all its extent—the new one of 1890 driven deep underground wherever possible, as a matter of preference, and built without surface disturbance except at the shafts and in one or two difficult places. To supply cities with water through such aqueducts, great dams are built or natural lakes are utilized. The fact that the lake or dam is to be fifty or more miles distant plays no part.

Perhaps the manufacture of shoes supplies as good an illustration as any of the substitution of factory for hand work in supplying domestic wants. The American shoe factory with its workshops filled with machinery and with trained operatives, each practiced in performing one single operation, using ingenious sewing machines, producing welt shoes or shoes without welt, sends its products to all parts of the world, and the hand made shoe is used less and less.

Foremost among the developments of the last half century is the India rubber industry. The discovery of the vulcanization of India rubber at once brought into the realm of practical uses a unique material, India rubber. At first it had been unsatisfactory, subject to change of qualities and uncertain in every way and affected by variations in temperature. But Goodyear's great invention of vulcanization produced a new and wonderful material, which has affected every department of modern life, and which, as not the least of its achievements, has created the modern pneumatic bicycle. It is hard to believe that this invention only goes back a little over fifty years.

In the march of progress the farmer has participated. Reaping, mowing, raking, harvesting, plowing, and cultivating, form but an incomplete statement of work now executed for him by machinery. Steam has long been used to do his work—now electricity is stepping in to his assistance, and we find an electric plow under trial. Patent churns, centrifugal and deep pan cream separators make his dairy work easy, and it is further simplified by the creamery to which he delivers his milk for butter and cheese making by machinery. To-day America exports cheese in enormous quantities, and many a tourist has eaten in foreign lands, under foreign titles, cheese from cheese factories of the Empire State.

The stock farmer who raises cattle for market to supply meat is not neglected. His market has expanded enormously, until the "roast beef of old England" has to be supplied by countries thousands of miles away from London. Cattle ships, which in all their appointments represent the finest marine engineering, receive them and they are dispatched across the ocean with as little concern or uncertainty as if it were a ferry which was to be crossed. The docks on the Thames receive steamer load after steamer load of cattle for the supply of the great metropolis and of the country at large. It really seems as if, without modern improvements, the world would have to go unfed. It would be fairer to say that it is the concentration of population in such centers as London and New York which has made it necessary to provide food supply by such methods. Under the conditions of former days, in a society more in accord with Mr. Ruskin's ideas, we might find the cattle ranges dotted with little villages, and London as yet not unified and consolidated, its constituent settlements still having independent existence. At present it is the other way, and there are in the West, deserted cities whose inhabitants were unable to resist the tendencies of the day. The cattle trade and food supply systems indicate the tendency of the world toward life in great centers of population. The deserted farms of New England, like the deserted cities of the West, tell the same story.

There is often a companionship in disease and its remedy. Cities grow large, and dwellers in the suburbs identify themselves with the metropolis. For their benefit special rapid transit methods are developed. It is very few years since the horse car was welcomed by the American city as an improvement on the old rattling omnibus. The writer recollects the day when there were many omnibus lines in New York and when the horse railroads of Philadelphia were an object of pride and rejoicing. Now all is changed. The horse railroad is archaic, and with a few exceptions in the way of compressed air, steam and electric motors, transit within city limits is done by central station methods. The city resident who desires to see the finest example of steam engineering has but to visit the power plant of his municipal railroad. The maintenance day after day and month after month of the great cable roads of

New York and other cities is a wonderful triumph of engineering practice. The electric trolley road is, however, the most powerful of these factors in what we have alluded to as the work remedial of the ills of modern centralization. From the central stations it sends its power lines in all directions through the suburbs of cities, and at almost nominal charge carries passengers for miles at a speed of ten to twenty miles an hour or more. The city worker is no longer obliged to live in closely built up streets. The cars escape to the region of green fields. The trolley may yet modify cities until they become centers of work and not of residence.

The trolley line with single overhead wire and rail and ground return is not a satisfactory thing. Much damage has been done by escape, or rather branching, of current from its rails. The underground trolley has been in use on a couple of roads, one in Ireland and one in Hungary, but only recently has it been introduced into America. The cities of Washington and New York have excellent examples of it. As it avoids the unsightly aerial wires, with attendant dangers, and as the underground system has two insulated conductors, avoiding destruction of pipes by electrolysis, the best wishes of civic engineers should be extended to it.

The self-contained motor car which can work independently of any central station is still in embryo. Many are in use, especially in Paris, but they are few in number compared to the central station car lines. A car motor needs such an exceptional reserve of power that the problem of devising an adequate motor for it is far from easy. The storage battery, for which such boundless fields of utility are open as soon as it shall become lighter and more practical, has been tried on street cars and operates a number to-day. The explosion oil engine may yet solve the problem. Hitherto the weight of the motor mechanism and the difficulty of establishing a sufficient reserve of power are the difficulties to be overcome.

We have already alluded to cold storage. Another domestic use to which the science of the day has been devoted is the production of ice. Ice formerly was harvested entirely from natural sources. Now it is made artificially in great quantities, and every first class ocean steamer or large steam yacht can make its own ice and cool its own refrigerators. In southern regions this art makes itself most directly felt, for Florida need no longer import ice from Maine. It can be made by machinery in quantities required for daily consumption.

The business man and the litterateur, even the newspaper reader, share in the advance. Quick processes of illustration have changed the daily journal into an illustrated publication, and color printing is used in it, as well as for works of the highest art.

The typewriter, a product really of the last twenty years, has effected a perfect revolution in the old time secretary's art. There is no longer the striving after a legible hand of definite style, but the even work of the typewriter makes the handwriting of a secretary a thing of no importance. The typewriter brings the writer's art in close juxtaposition with that of the printer, and, following out the analogy, we find the modern printer in possession of machines for composing.

It has long been a dream with inventors to do away with the hand composition. Early in the fifties William Mitchell's type-setting and distributing machines were experimented with at the Trow printing office, in this city, and were used for some years there. Other inventors attacked the problem in other ways; some devoted their efforts to the production of a matrix, by means of which a stereotype or electrotype could be produced. At last the idea of a matrix-setting in contradistinction to a type-setting machine occurred, and a complicated and highly ingenious machine was invented for carrying out this idea. This machine, the Mergenthaler, so called Linotype machine (which might more properly be written Lineotype), set, by means of a key-board, individual letter moulds or matrices. For justification, wedge-shaped spaces or quads were used. These were inserted between words, and when the line was nearly filled and a syllabic division or end of a word was reached, the line was completed by thrusting in the wedges. This accomplished the missing function of preceding machines—the machine did its own justification. When a line of moulds were set up the casting of metal against their faces was automatically done, and a "slug" of one complete line of text resulted. Quantities of printer's work is now done on machines of this class. It marks the solution of a problem of four centuries' standing.

A very important line of work is in the field of the gas and oil explosion engines. In these we have a long range of temperature change acting to reduce the low economy due to the second law of thermodynamics. These machines are now made without ignition tube, flame or electric spark igniter, and, as they operate without boiler and require scarcely any attention, they go far to bring power within the use of all. Ericsson, Roper, and others have done well in a parallel line of work with hot air engines, and the entire subject of displacement of the steam engine is affected by them as well as by electric motors. These smaller motors, because they require so little plant, are now entering into the daily life of the individual. They are used in small machine shops, small boats are driven by them, and industrial conditions may yet be gravely modified by the possibility of economically producing small units of power with small investment of capital.

While this indicates the possibility of the division of industries into small units, we are confronted on the other hand by immense industrial settlements, the tendency of the day having brought about consolidation of interests. Thus we have the car shops of Pullman, Ill., supporting a city. We see the great Carnegie Iron Works, at Homestead, Pa., covering 110 acres of ground and employing 8,000 men, a veritable industrial army, beyond the imaginations of the past generation.

Formerly watches and clocks were individual creations, the tradesman turning out the finished product from his little shop. Now the great factory produces them, employing every refinement of automatic machinery and specialized labor, the principle of interchangeability affecting the product to the last degree. The foreign industry has been profoundly affected, and the New England timekeeper equals in quality the best hand-made product of an earlier day.

Our theme in this retrospect has been the wonder of it all, and in that wonder every few years an awakening is observed which finds expression in what has become an institution of the last fifty years—great expositions. Started in England by Prince Albert, the Consort of Queen Victoria, with the World's Fair of 1851, held in London, every few years have witnessed the inauguration of a new exposition. After having been started as world's fairs and exhibitions of the industry of all nations, they have become differentiated and special exhibitions have been prepared, covering either special articles or special countries, and lately these exhibitions have been very numerous. But the long series is punctuated throughout at intervals of a few years by real world's fairs, each one in splendor and completeness striving to outdo its predecessor, until, in 1893, at the great Western metropolis, all former efforts were eclipsed by the Columbian Exposition, designed to commemorate the discovery of America by the great Genoese. It was an exposition where a mingling of history and art led to the erection of the most magnificent group of buildings and architectural trophies that the world has ever seen—where the water from the lake made easy the introduction of water into the scene, which water, circulating in beautiful lagoons, was traversed by the Venetian gondola, the relic of past centuries, and by the electric launch, the production of the very moment—where the most beautiful art products of the world were fairly rivaled in interest by the trophies of the mechanics' and technologists' art—where in the reproduction of the features of life in foreign lands the human element was made to vie in interest with all the rest. The great fair ended, far outdoing anything that the world had ever seen. The destruction of its buildings by fire formed a fitting culmination of its necessarily short life. It is hard to be believed that it will soon be surpassed. It seems to represent the proper ending of the nearly fifty years period during which such fairs have been held.

THE PATENT SYSTEM.

Up to the end of the year 1845, 3,873 patents had been issued by the Patent Office of the United States. When the year 1895 closed its course, the number was 531,619, a wonderful tribute to the inventive genius of the American people and more wonderful because out of this great number comparatively few were issued to foreigners. The largeness of the number is a tribute to the far sighted liberality of the patent statutes, originally established by our forefathers in the days when the individual counted for far more than in the present day of fierce competition and wealthy combinations of capitalists. Even in those days, it was recognized that the individual inventor required the fostering protection of the law, and it was known that the best possible policy for the country was to grant him this protection for the enrichment of others and for the good of the country at large. In the first days of the republic exceedingly few patents were granted, but about 1845 the system was in full operation and the American nation already began to be noted for its inventive powers. The training of years of privation and isolation which characterized life in the sparsely settled region had caused the American people to be self-reliant. A farmer separated many miles perhaps from the blacksmith shop, with absolutely no machine shop within reach, with carpenters and other tradesmen few and far between, learned to do everything himself, and it was unquestionable that in these early days the farmers of America displayed a high order of constructive and mechanical skill and a quick adaptation to circumstances that have now imprinted themselves upon the entire American people. To-day the farmer has complicated machinery to take care of, and he does it successfully; small repairs he executes himself, and in him is found the true material that inventors are made of.

The American race seeming by the force of circumstances to be destined to be mechanical, have developed among themselves a special genus or race, that of inventors, men who have been termed by the courts of highest standing geniuses—men who in their work exercise the undefinable quality of invention—the most difficult statutory requirement which the courts ever have to define; and it is this race of inventors who spend their lives far too often in perpetual striving and in poverty, while really working for the good of humanity, in the simple hope that their efforts will be appreciated by the cold business sense of mankind and that the selfish interest of the world will give them their reward. They and their work are the constant exponents of the theory of the patent statutes, a theory little understood, and one which it seems as if the very courts of law themselves sometimes fail to grasp, and for whose enlightened elucidation the decisions of old time judges, the ornaments of the American judicial bench, can be appealed to with the certainty that the inventor will there receive his due.

The theory of the patent law is simple. The country is enriched by inventions, and offers for them a small premium; this premium is a seventeen years' monopoly of their fruit—no more, no less. Having purchased the invention for this insignificant price, the purchase is consummated by the publication in the patent records of the details of the invention, so that he who runs may read. The whole thing is a strictly business transaction, and this character is emphasized by the fact that the inventor is required to pay for the clerical and expert labor required to put his invention into shape for issuing. His patent fees are designed to cover this expense, and do so, with a considerable margin to spare. Thus the people of the United States are perpetually being enriched by the work of inventors, at absolutely no cost to themselves.

The inventor does not work for love nor for glory alone, but in the hopes of a return for his labor. Glory, and love of his species, are elements actuating his work, and in many cases he invents because he cannot help himself, because his genius is a hard task master and keeps him at work. But none the less, the great incitement to invention is the hope of obtaining a valuable patent, and without this inducement inventions would be few and far between, and America would, without the patent system, be far in arrears of the rest of the world, instead of leading it, as it does to-day. The few pregnant sentences of the patent statutes, sentences the force of whose every word has been laboriously adjudicated by our highest tribunal, the Supreme Court of the United States, are responsible for America's most characteristic element of prosperity, the work of her inventors.

It would be idle to attempt to recapitulate here the great inventions of the last fifty years, for their name is legion. Morse's unequaled work in telegraphy, Reis' pathetic struggle to invent the telephone; the development of the dynamo by a host of ingenious inventors; the development of the compound and multiple expansion steam engine from the engine of fifty years ago, which was practically what was left by the great inventor Watt from the last century; the unequaled inventions in the world of steel, in bridge building and in naval engineering; the sewing machine; typewriters; these and myriad others will occur to the reader of our columns, and from the contemplation of it all but one moral can be drawn, one lesson deduced. We are indebted for most of this progress to the patent system. America's progress is a direct plea for the protection of the inventor.

Take away from the inventor the pecuniary reward of his invention, and what stimulus is there, especially if he be a poor man, for him to devote his time and energies to the development of his ideas? Those who read in these pages of the struggle against poverty of Morse and Howe and Wilson and a score of others while they were developing their inventions, will understand that finally these men received the reward for their unswerving devotion to their work. The sewing machine industry is a case in point; while the patents remained in force, the business was enormously profitable, and these machines of American invention were introduced all over the world. Several of the large companies have taken up the manufacture of bicycles, while others have been forced into bankruptcy.

If the American patent system be changed in any way, the path of the inventor should be made an easier one and his rights should be more sedulously guarded than ever. The work of invention is going on in all lands, and any cessation in activity on the part of the American inventor will go to reduce America's rank in the world of nations. In the present epoch, a very short period will be required to leave us hopelessly distanced in the competition. Any blow at her inventors will be a blow at the very heart of America's industrial life and material and intellectual prosperity, and it is hard to believe that such a blow will ever be given.

The following figures give an idea of the development of American inventions during the past fifty years:

United States patents and reissues issued in 1845	508
" " " " 1855	2,018
" " " " 1865	6,616
" " " " 1875	14,837
" " " " 1885	24,233
" " " " 1895	22,057
Greatest number issued in any year since 1845, 1890	26,292
Smallest " " " " 1845	508
Patents issued for carriages and wagons	20,821
" " stoves and furnaces	18,972
" " electrical inventions	16,062
" " clasps, buckles and buttons	13,177
" " packing and storing vessels	11,588
" " plows	10,342
" " harvesters	10,324
" " mills	10,046
Class for which smallest number of patents were issued:	
Silk	106

THE TRANSATLANTIC STEAMSHIP.

In tracing the history of the part played by the United States in the development of the transatlantic steamship during the past fifty years, it will be a pardonable inconsistency to run back some seventy-five years to an earlier date and make mention of the first steamship that made the transatlantic passage—the American-built Savannah. During the latter part of May, in the year 1819, this little craft of about 350 tons sailed from Savannah, Georgia, and, after a prosperous voyage of 28 days, lasting from May 22 to June 20, she anchored in the Mersey, having made use of steam for eighty hours of the time occupied by the trip to Liverpool. She was built on the East River, New York, and was originally designed as a sailing packet; and, if we may judge from the old engravings, her sail plan does not appear to have been cut down to any extent after the engines were introduced. This latter work was done at Savannah, Georgia, where she was prepared for her new venture by her owners, William Scarborough and others. The engines were direct acting, and the paddle wheels were so constructed that in stormy weather they could be unshipped and stowed on deck. She had stowage capacity for 70 tons of coal and 25 cords of wood.

The distinction of having built the first steamship that ever crossed the ocean, propelled all the way by steam, belongs to the western world. The feat was performed by a Canadian-built vessel, the Royal William, which, in 1833, made the passage from Quebec to London. This performance, together with the passage of the steam-equipped Savannah, fourteen years before, makes it evident that the credit of originating transatlantic navigation should be accorded to the New World. It was fitting and natural that it should be so. River navigation had proved so successful that the steamship builder naturally turned his thoughts to the ocean, and it was a logical step from the prudence which made only a partial introduction of steam in the Savannah to the more ambitious attempt to equip the Royal William with steam power and fuel capacity sufficient for an entire passage.

The first American steamer built expressly for the Atlantic trade was the United States. She was constructed at New York by William H. Webb for the Black Ball line of packet ships. Her first voyage was made to Liverpool in 1847, and lasted 13 days. She was a splendid steam vessel for those days, being of 2,000 tons burden and measuring 256 feet in length by 50 feet beam, and 30½ feet in depth. She has the distinction of being the first merchant steamship constructed for naval use as a cruiser, provision being made for arming her with two tiers of guns. Her life in the merchant marine, however, was short, for, after making one round trip to Liverpool, she was purchased by the Prussian government for use in their navy as a steam frigate.

Following the United States came the Washington, of 1,700 tons, and the Hermann, of 1,800 tons, built in 1847 to run between New York and Bremen; the Franklin, of 2,400 tons, built in 1848 to run between New York and Havre, to which, in 1850, was added the Humboldt, of 2,850 tons. These two ships were owned by the New York and Havre Steam Navigation Company, who received a subsidy of $150,000 a year for carrying the mails.

It was during this decade that a ship was launched on the other side of the water which, although it does not represent American development of the ocean steamship, gave so powerful a stimulus to ocean navigation that it claims a passing notice. This was the first iron transatlantic steamship, Great Britain. She was designed by that distinguished engineer Brunel, and, like many other of his creations, marked a great advance upon anything previously attempted. She was approximately a 3,200 ton vessel, and therefore as large again as any transatlantic ship of her day. Her length was 322 feet, beam 51 feet, and her depth 32 feet 6 inches. Brunel showed his far-sighted appreciation of the value of screw propulsion by discarding the paddle wheel and fitting her with a screw propeller; and by the substitution of iron for wood, and the screw for the paddle wheel in this one ship, he introduced two factors which have contributed immensely to the efficiency of the transatlantic steamship. An engraving and a detailed description of this remarkable ship is to be found in the first issue of the SCIENTIFIC AMERICAN, published by Munn & Company, a facsimile of which will be found on the front page of this issue. Her first passage was accomplished in 15 days, at an average speed of 9 knots an hour.

THE UNITED STATES—1847—THE FIRST AMERICAN STEAMER BUILT EXPRESSLY FOR THE ATLANTIC TRADE. TONNAGE, 2,000.

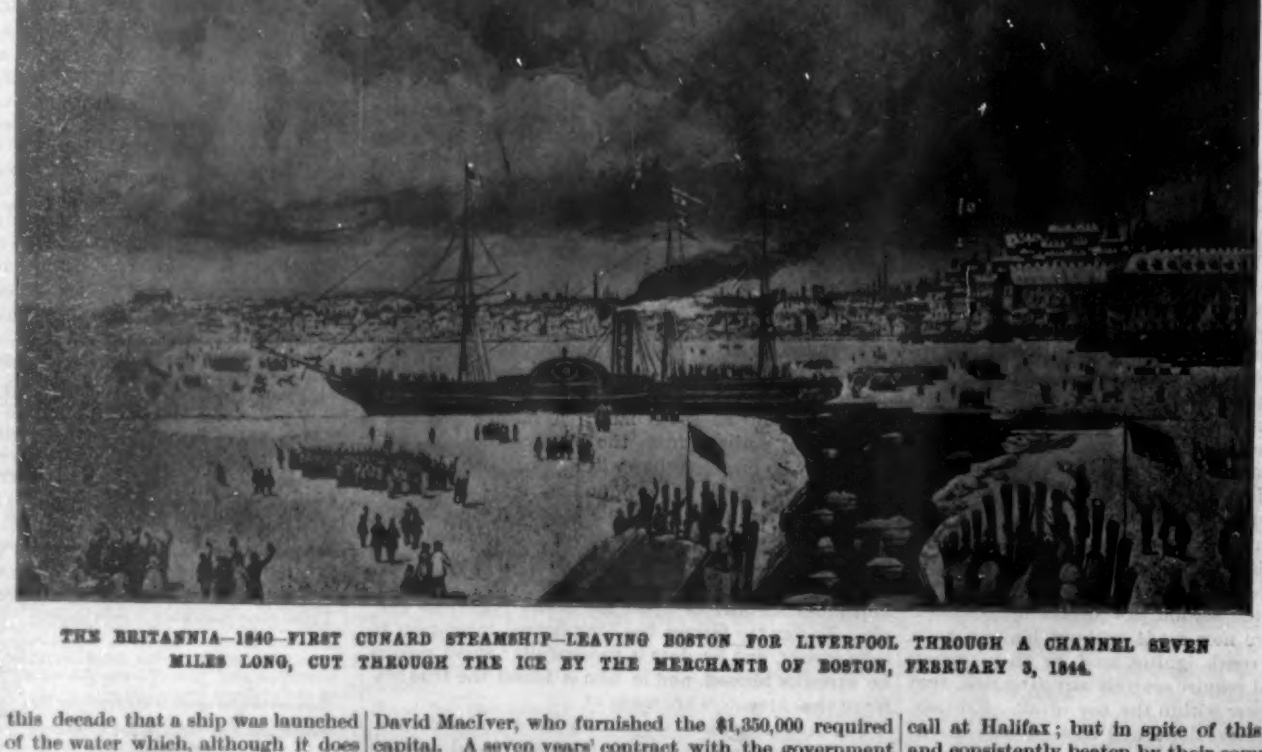
Before passing on to a consideration of the ships of the celebrated Collins line, and by way of introduction to this distinctively American venture, it is necessary to linger awhile on the other side of the Atlantic, and take note of the origin and early development of the famous Cunard line, which was the first company to bind itself to maintain a regular service with fixed dates of departure from each side of the Atlantic. Briefly told, the story of the foundation of this great enterprise is as follows: At the close of the fourth decade of the century, a Mr. Samuel Cunard, of Halifax, Nova Scotia, who was conducting a mail service between Boston, Newfoundland and Bermuda, received a copy of an Admiralty circular calling for tenders for a steam packet service across the Atlantic. Failing to get assistance in Canada, he crossed to Liverpool, where he fell in with Robert Napier, the engineer and shipbuilder, and through him met George Burns and David MacIver, who furnished the $1,350,000 required capital. A seven years' contract with the government was forthwith signed, by which the company were to provide four steamers and dispatch one of them from Liverpool for Halifax and Boston on the 4th and 19th of every month from March to October, and on the 4th of each of the four winter months. For this they were to receive $400,000 per year.

The ships were of 2,050 tons displacement, being 207 feet long, 34½ feet broad and 22½ feet deep. The engines were of 403 nominal horse power, and the coal consumption was 38 tons a day. They carried 640 tons of coal, 225 tons of cargo, and 90 first-class passengers, and their speed was 8¼ knots an hour.

The Britannia, the first of the four ships, started on her maiden trip from Liverpool on July 4, 1840, and on July 19 was received in Boston with unbounded enthusiasm. The new line was immensely popular with the Boston citizens, and when, in February, 1844, the Britannia was frozen up in the harbor, the merchants of Boston, at their own expense, cut a channel seven miles long through the ice to the open sea, through which the ship sailed on the appointed day. This voluntary work cost no less than $20,000.

During the ten years 1840–50 the Cunard ships held all but undisputed control of the steamship traffic between America and England, and it was the inroads which they were making upon the trade of the celebrated American clippers which, in 1845, led the owners to equip one of these vessels, the Massachusetts, with an auxiliary screw. In 1847 the public enthusiasm in America was aroused by the dispatch of the Washington to Bremen by way of Southampton, on the same day as the Britannia sailed for Liverpool. The Britannia won the race by two days. "The popular enthusiasm on the subject was sufficient to overcome the reluctance of Congress to grant a subsidy, and a company was formed under the management of Mr. E. K. Collins, of New York, to establish a line of American steamers between that port and Liverpool."

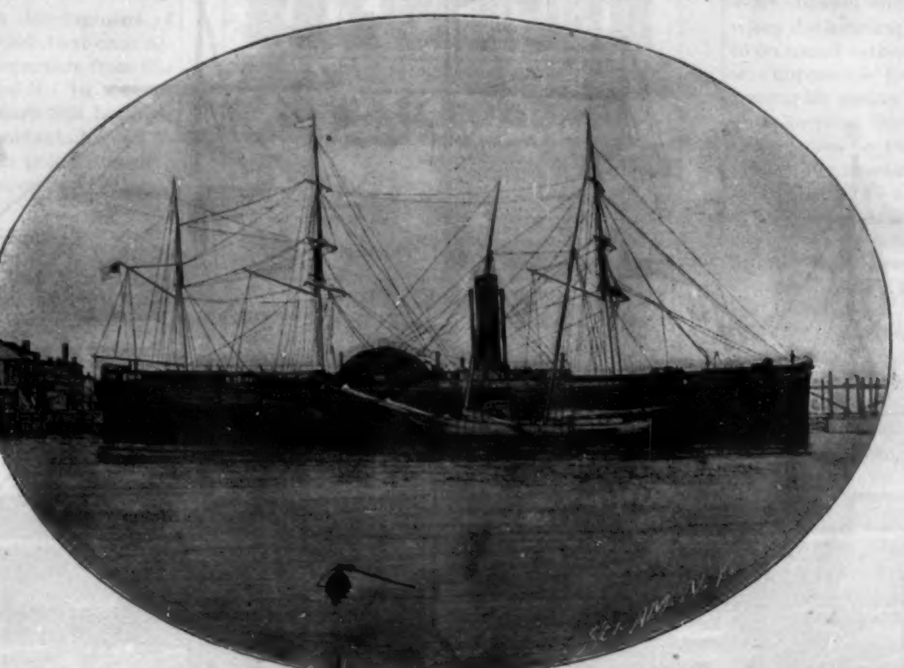
It was clearly foreseen that if the new American ships were to compete successfully against the powerful and popular Cunard line of steamers, they would have to surpass the latter in both size and speed. Four ships were determined upon; and encouraged by a government subsidy of $385,000, and the payment of $415,867 for carrying the mails, the company spared no expense to make them the finest specimens of marine architecture afloat. The splendid record of the Collins sailing ships made it certain that the model of the new ships would be suitable for high speed, and the design of the machinery was intrusted to Messrs. Sewell and Faron, chief engineers of the United States navy. Mr. Faron was sent to England to inspect the machinery and ascertain the boiler pressure of the largest Cunard boats, and on his reporting that they carried thirteen pounds to the square inch in the boilers, it was determined to give the new ships sufficiently larger engines, with the same boiler pressure, to insure their equaling the speed of the Cunard boats. The construction of the four ships was pushed through with all dispatch, and in 1850 the American company had four ships afloat, which in size, speed, luxurious accommodation, and general beauty of finish were admitted, even by the rival company, to be in advance of anything afloat at that time. Then began a fierce struggle for the blue ribbon of the seas, and the triumphs of the famous sailing ships of this company were repeated in the brilliant success of their steam fleet. To save time on the passage, the Cunard line ceased to call at Halifax; but in spite of this they were easily and consistently beaten by their competitors.



THE BRITANNIA—1840—FIRST CUNARD STEAMSHIP—LEAVING BOSTON FOR LIVERPOOL THROUGH A CHANNEL SEVEN MILES LONG, CUT THROUGH THE ICE BY THE MERCHANTS OF BOSTON, FEBRUARY 3, 1844.

The Pacific of the new line was the first ship to make the passage from New York to Liverpool in less than 10 days, her time during a passage in May, 1851, being 9 days, 20 hours, 16 minutes, and in February of the

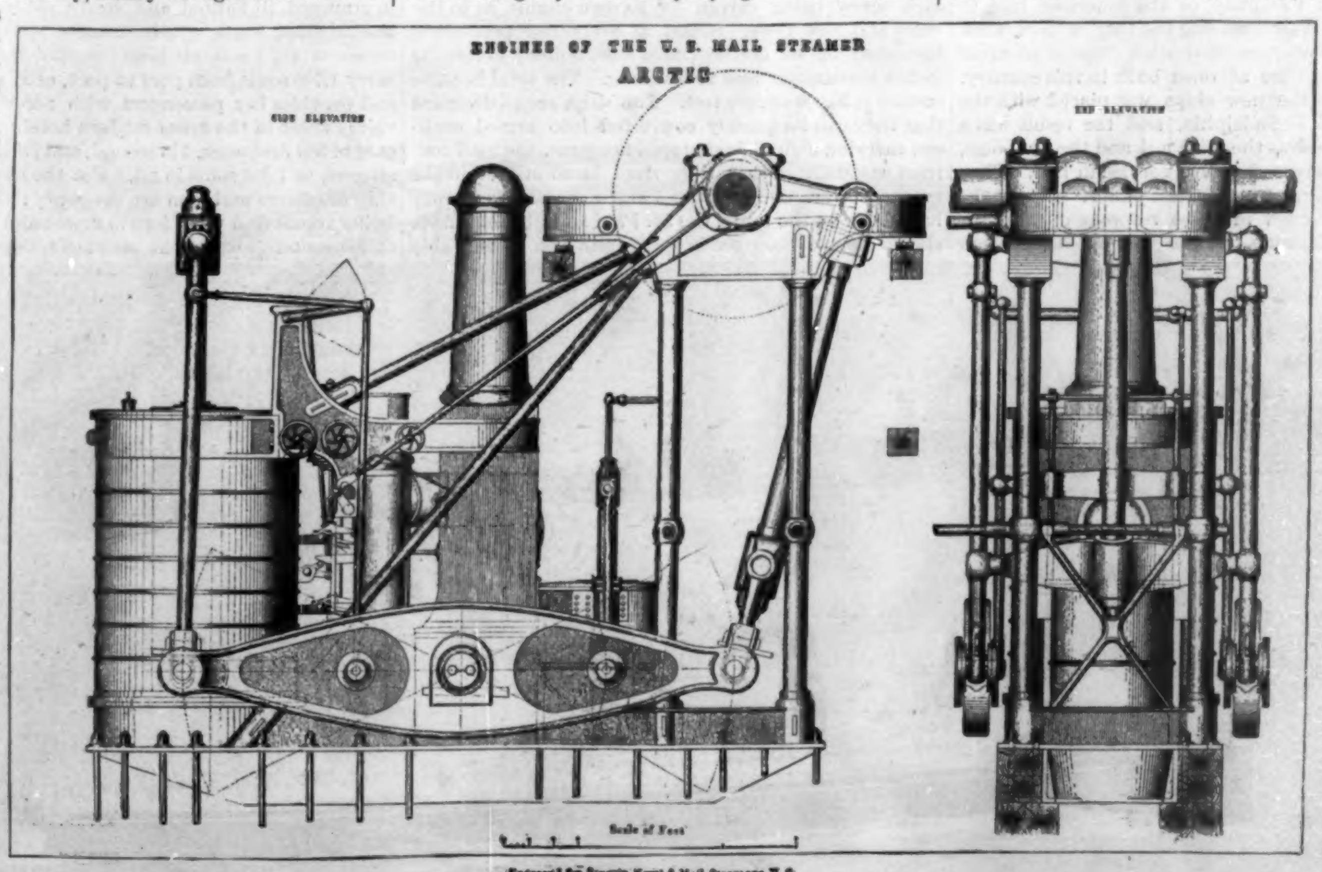
next year the Arctic broke the record by crossing in 9 days, 17 hours, 12 minutes. How complete was the supremacy of this line may be judged from the fact that the average time of the Collins boats in crossing from New York to Liverpool during the year 1852 was 1 day 6 hours and 18 minutes less than that of the rival line. The Collins line secured the larger share of the passenger traffic, carrying between January and November, 1853, 4,306 passengers, against 2,969 carried by the Cunard company. The illustration of the Arctic herewith reproduced from Stuart's "Naval and Mail Steamers" was originally engraved from a daguerreotype, which was taken as she lay at her moorings at the foot of Canal Street, New York, and may be relied on as a faithful representation of these vessels. It will be seen that they were characterized by the high freeboard which has always been an excellent feature of American practice, and this, no doubt, contributed largely to their seaworthiness and comfort in heavy weather. The Arctic was 282 feet long by 45 feet beam and 32 feet deep, and her tonnage was 2,860. The engines were of the side lever condensing type, with cast iron beams and wrought iron columns and braces. The valves were of the balance poppet variety. The boilers, which were specially designed by Mr. Faron for these boats, were square in cross section, and carried about 17 pounds of steam. To secure a powerful draught the smokestack was made unusually lofty, the top being 75 feet from the firebars. The average performance of the Arctic during February, 1852, was as follows: Boiler pressure, 16·9 pounds; revolutions, 15·8 per minute; coal consumption per day, 84·3 tons; speed, 316·4 knots per day. Her greatest day's run was 320 knots, at the rate of 13·3 knots per hour, a splendid record for those early days. The Collins venture, which opened so brilliantly, closed with disaster. The Arctic was sunk by collision in 1854, and went down with 520 souls. A year later the Pacific left Liverpool never to be heard of again. In spite of these losses, in the following year the company launched the Adriatic, of 4,144 tons, a superb vessel; but the persistent efforts of the Cunard company, who, in 1855, launched the Persia, a 3,870 ton iron steamer of about 14 knots speed, coupled with these heavy losses and the withdrawal of the government subsidy, finally brought about the dissolution of this famous company. The sailing of these ships was taken up by the Inman, now the American line, of which mention will be made later.



THE UNITED STATES MAIL STEAMER ARCTIC, 2,860 TONS, OF THE COLLINS LINE—GREYHOUND OF THE ATLANTIC IN 1852. TIME, 9 DAYS, 17 HOURS, 12 MINUTES.

American interests on the Atlantic subsequent to the decease of the Collins line were represented by the Fulton, of 2,061 tons, and Arago, of 2,260 tons, and the famous Vanderbilt, of 3,360 tons burden, the latter, launched in 1855, being the fastest ocean steamship of her day. She crossed eastward in 9 days, 8 hours, and westward in 9 days, 9 hours and 24 minutes.

In the year 1853 a company was formed in England to construct a steamship which could make the round trip to Australia and back at a speed of 18 knots, and carry sufficient coal for the purpose. Mr. Brunel was intrusted with the designs, and the result was the Great Eastern, a ship which even to-day would dwarf our biggest ships by her huge proportions. Like the Great Britain, she showed the free hand and inventive genius of her designer. She was in every detail a splendidly built ship, both as regards hull and engines. Her dimensions were: Length, 680 feet; breadth over paddle boxes, 118 feet; beam, 83½ feet; depth, 58 feet; draught, 30 feet; displacement, 32,160 tons; tonnage, 22,500; cargo storage, 6,000 tons; coal storage, 12,000 tons; diameter of paddle wheels, 56 feet. She was driven by paddle wheels and a screw propeller, each of which was provided with separate engines and boilers. Launched in 1858, she cost complete no less than $3,650,000. Her maiden trip was made from Southampton to New York in 1860, her highest speed during the trip being 14½ knots an hour, and her longest day's run 333 miles. She consumed on the trip 2,877 tons of coal. The Great Eastern was of such colossal size that she was but little affected by wind and weather, and except on one occasion, when she was disabled and fell off into the trough of the sea, passengers testified to her easy motion in the heaviest storms that were encountered. Commercially considered, however, she was a complete failure from the very start. But though she was disastrous to her owners, she conferred an incalculable boon upon the world at large by successfully laying the first Atlantic cable in 1866. After doing various, but always unprofitable, work, she laid two more Atlantic cables in 1873 and 1874. She was finally, in 1888, sold for old iron and broken up at Liverpool.



SIDE LEVER CONDENSING ENGINES OF THE ARCTIC.

Soon after the withdrawal of the Collins line there came the great civil war, with its disastrous effects upon American shipping interests. So effective were the depredations of the Confederate cruisers, that the American merchant marine was practically swept from the seas, and at the close of the war we were not only weakened by actual losses, and the general discouragement of commercial enterprise, but foreign maritime nations were proportionately enriched.

A few official figures tell the story of this decline more eloquently than any multiplication of words. The total number of steam and sailing vessels built in the United States in 1847 was 1,597; this fell in 1862 to 864, and in 1895 to 694. On the other hand, the total tonnage of vessels sold to foreigners in 1847 was 16,969; in 1861 it was 26,649 tons; in 1862 it rose to 117,756 tons, and in 1864 to 300,865 tons!

It is not surprising that at the close of the war American capital looked with distrust at marine transportation, and directed its energies to the development of the vast internal resources of the country; and with what energy it did so is shown in the marvelous growth of the railroads during the next forty years. The development of the transatlantic steamship was left entirely in the hands of the English and European builders, and as the scope of the present review covers mainly the American share in this development, it will be sufficient to indicate the progress abroad by noting briefly its most important advances.

The screw was now rapidly driving out the paddle wheel, the Scotia, a 3,870 ton ship, being the last of the latter type built for the Cunard line. She was the first to make the passage in less than 9 days, covering the distance in 8 days, 3 hours, in 1863. To the Inman, now the American line, is due the credit of bringing the time of passage below 8 days, a feat accomplished in 1869, by the City of Brussels, a 3,747 ton screw steamer, whose time was 7 days, 22 hours, 3 minutes. The year 1871 was marked by the advent of the White Star line, whose boats, the Oceanic and Adriatic, introduced many new features conducive to the comfort of travel, and maintained a high standard of speed and regularity. The 7 days limit was first passed by the Alaska, of the Guion line, which made the trip, in 1882, in 6 days, 22 hours; and the credit of bringing the time below 6 days belongs to the City of Paris, of the Inman line (now the Paris of the American line), which, in 1889, made the westward passage in 5 days, 19 hours and 18 minutes. The present record of 5 days, 7 hours and 23 minutes is held by the Lucania, of the Cunard line.

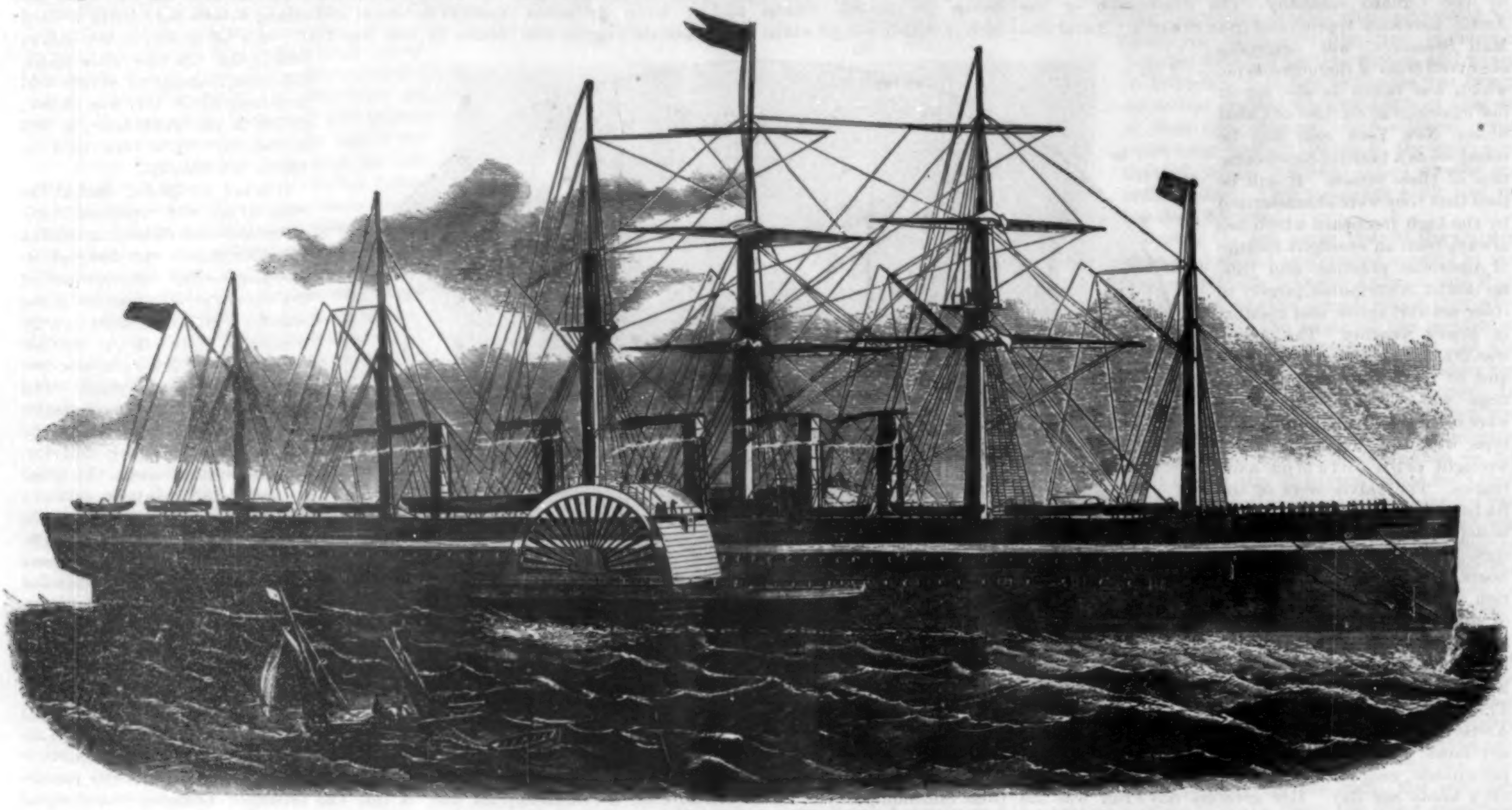
Although with the exception of the four ships built for the American line of 1870, we took little part in the construction of Atlantic steamships during these forty years, American capital was largely interested in the celebrated Inman line, which started out in 1850 with two iron, screw propelled ships. Since that time they have been fully abreast, if not ahead, of any other company in the adoption of the various improvements which have made the steamship what it is to-day. Their early steamers were all of iron and fitted with the screw propeller; they adopted the compound engine with its higher boiler pressure and consequent economy in fuel; and in 1889 and 1890, after the company had been reorganized as the In-

man and International Company, they made another radical departure in that magnificent pair of ships the City of New York and the City of Paris, which were the first to be furnished with twin screws combined with triple expansion engines. These boats were, in every respect, a great advance upon anything built or planned at that date. Their 10,500 tonnage, their 20,000 indicated horse power distributed between two engines, in separate watertight compartments, their speed, and every detail of their furnishings and equipment, were a fresh evidence of the old time farsightedness and liberality of the Inman line.

In order to encourage the building up of the American merchant marine, the Congress of the United States, in 1892, passed a special law by which authority was given to this company, now known as the International Navigation Company, or the American line, to place under the American flag the City of New York and the City of Paris, provided other ships of an equal tonnage and speed were at once built in this country. The contract for the new ships was placed with the Messrs. Cramp, of Philadelphia, and the result was a noble pair of vessels, the St. Paul and the St. Louis, which both commenced active service in 1895. They are the second largest and fastest pair of ships in the world, being exceeded in these respects only by the Campania and Lucania, of the Cunard line. Their principal dimensions are: Length over all, 554 feet; breadth, 63 feet; moulded depth, 42 feet; gross register, 11,629 tons. They are built of steel, with a double bottom, and a minute cellular subdivision. They are so subdivided by athwartship bulkheads that, if two adjoining compartments were flooded, they would have an ample margin of flotation. The quadruple expansion engines which we illustrated in a recent issue aggregate about 20,000 horse power. An interesting comparison can be made between them and the Arctic's engine, shown on another page. The St. Paul has two sets of engines, each of which has six cylinders, arranged over four cranks, the first pair of cranks being driven by a pair of high pressure and low pressure cylinders in tandem, the remaining cranks being each driven by first and second intermediates. The screws are three bladed, each screw being driven by its own engine, as in the Paris and New York. Steam at 200 pounds pressure is furnished by six double-ended steel boilers, 15 feet 7½ inches in diameter and 20 feet long. The total heating surface is 30,000 square feet. The ships are so designed that they can be quickly converted into armed cruisers, carrying eight 6 inch rapid fire guns, the mail contract stipulating that they shall be so utilized in the event of war. During the twelve months that they have been on the route, the St. Paul and St. Louis have shown a steady increase in speed, and the former ship now holds the record from Southampton to New York, having crossed in 6 days, 5 hours and 22 minutes, at an average speed of 20·82 knots, the longest day's run being 521·9 knots, at an average speed of over 21 knots an hour. This performance has been exceeded, it is true, by the Lucania and Campania, ships of 13,000 tons displacement, the former of which has an average speed record of 22 knots an hour for the whole trip. As the latter is equipped with 30,000 horse power against the 20,000 horse power of the St. Paul, it will be seen that, judged as a relative performance, that of the St. Paul is the more creditable.

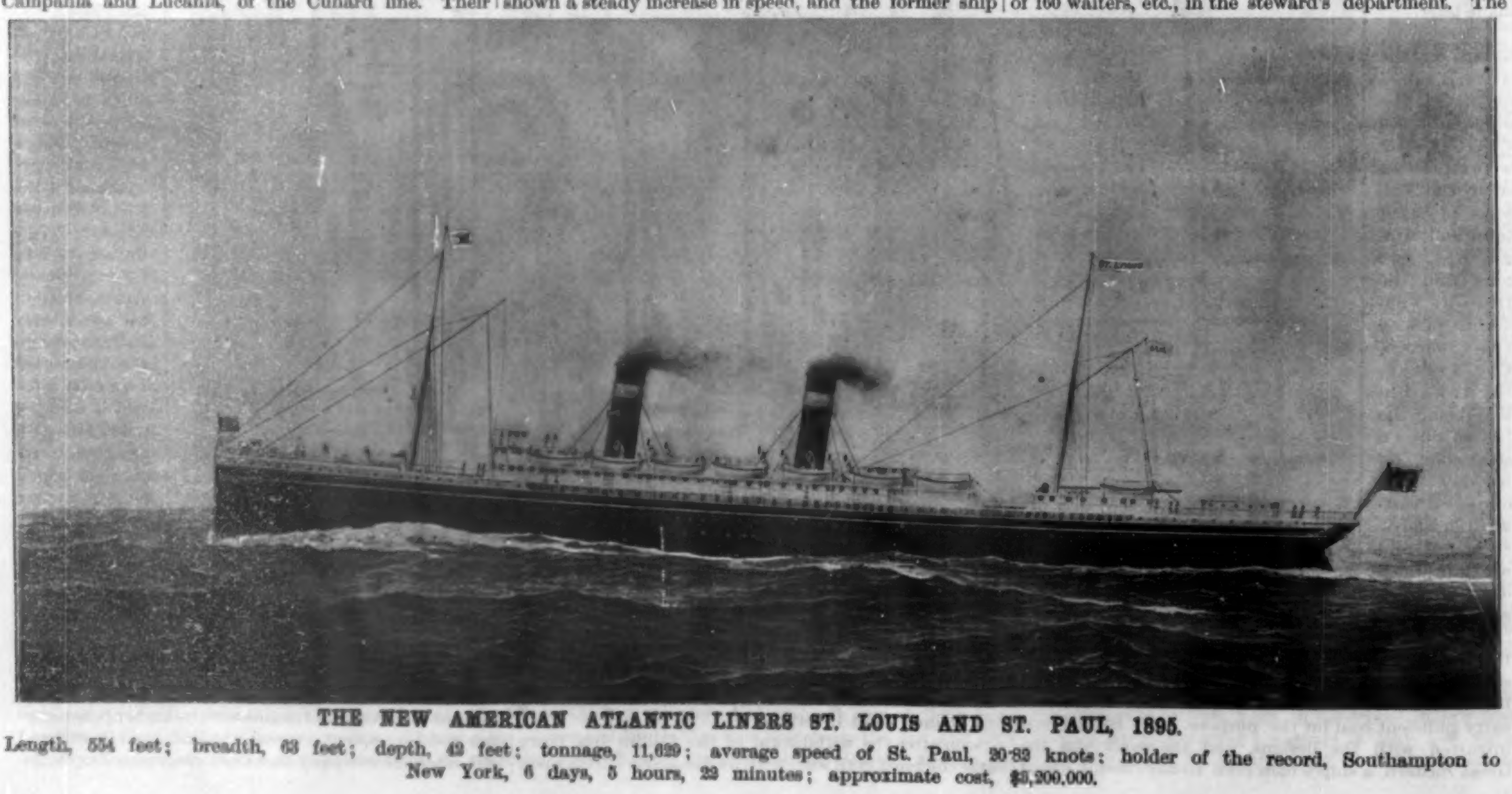
Space forbids a more detailed description of these, the latest additions to the great transatlantic fleet of steamships.

Fifty years ago, a few score passengers were carried in cramped, ill-lighted and stuffy cabins, upon small paddlewheel boats, which dragged wearily across the ocean at 8½ knots an hour; to-day, the St. Paul can carry 1,700 souls from port to port, at 21 knots an hour, and provides her passengers with accommodations rivaling those of the finest modern hotel. She can take care of 360 first-class, 175 second, and 775 third-class passengers, or 1,310 souls in all. For the navigation of the ship 60 officers and men are necessary; the engine and boiler rooms find work for 175 more; and there is a staff of 160 waiters, etc., in the steward's department. The



THE GREAT EASTERN, LAUNCHED 1858.

Length, 680 feet; breadth, 83½ feet; breadth over paddle boxes, 118 feet; depth, 58 feet; draught, 30 feet; displacement, 32,160 tons; tonnage, 22,500; average speed, 11·23 knots; time, Southampton to New York, 11 days; cost, $3,650,000.



THE NEW AMERICAN ATLANTIC LINERS ST. LOUIS AND ST. PAUL, 1895.

Length, 554 feet; breadth, 63 feet; depth, 42 feet; tonnage, 11,629; average speed of St. Paul, 20·82 knots; holder of the record, Southampton to New York, 6 days, 5 hours, 22 minutes; approximate cost, $2,200,000.

expenses of such a ship are, necessarily, enormous, one of the great English companies having recently admitted that they run as high as $5,000 a day with a full complement of passengers. To furnish the 20,000 horse power for the engines of the St. Paul requires the consumption of 310 tons of coal per day; and the consumption of provisions by the passengers can be judged from the list of supplies carried for one trip, some of the items being as follows: 30,000 pounds of beef, 10,000 clams and oysters, 500 pounds of coffee, 3,000 pounds of butter, 3,000 pounds of sugar, 16 tons of potatoes, 15,000 eggs, and 140 barrels of flour.

In tracing the various stages of the development of the transatlantic steamship, it is found that each decade was marked by some radical departure from the practice of the decade which preceded it. In the accompanying table it is attempted to mark this progress approximately, showing the most important changes in construction, the approximate rise in boiler pressure, and the approximate improvement in engine performance:

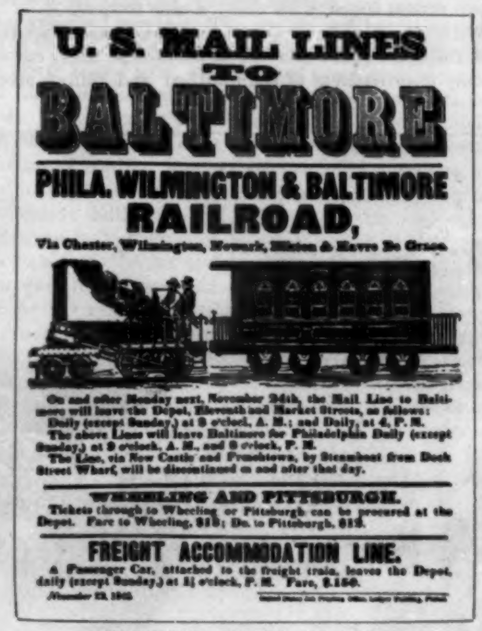
Decade.	Development in construction.	Approximate boiler pressure.	Approximate lb. of coal per horse power.
1845-55	Iron in place of wood	10 to 20	4·5 to 3·5
1855-65	Screw in place of paddle wheel	20 " 35	3·5 " 2·9
1865-75	Compound in place of simple engines	35 " 60	2·9 " 2·2
1875-85	Steel in place of iron, and triple expansion engines	60 " 125	2·2 " 1·9
1885-95	Twin screws, quadruple expansion and forced draught	125 " 200	1·9 " 1·3

Space forbids a more extended treatment of a subject which has an increasing interest for all patriotic Americans; but enough has been said to show that the part played by the United States in the development of the transatlantic steamship has been far more extended and important than is perhaps generally supposed. It dates from the earliest records, when the Savannah opened the very first chapter of its history by her memorable voyage to Liverpool; and the easy triumphs of the Collins line in the fifties bid fair to be repeated in the history of the American line of to-day.

RAILROADS AND BRIDGES.

The railroad system of the United States is remarkable, alike for the rapidity and proportions of its growth, and for the fact that it expresses the adaptiveness and ingenuity of the American people more, perhaps, than any other field of enterprise to which they have directed their energy and capital. In the whole range of engineering work there is nothing more distinctively American than the American railroad; nowhere is the national faculty of adapting the means to the end more consistently manifest than in the development of this vast system of transportation. From its cheap prairie track, built at $15,000 a mile, to its superb "limited" trains, with their full complement of costly parlor, sleeping and dining cars, the whole system is the outcome of an attempt to satisfy the luxurious tastes of a people who were scattered over a vast area of more or less undeveloped country.

It was realized at the outset that it was neither



RAILROAD POSTER OF 1845.

expedient nor possible to build American railroads according to the expensive methods of European engineers. The conditions in the two countries were entirely different. The early roads in England and on the Continent were built through populous districts, and between large cities, and the day of the opening of a new line found passengers on every platform and freight in every yard. Large receipts were assured and dividends were certain. Hence it was good policy to construct the roadbed in the most solid manner, and lay out the line with a view to economy of operation. Hills were tunneled, deep cuttings opened, massive embankments raised, and every expedient known to the engineer and contractor was used in the effort to produce a line that should be at once level and straight. The result, as in the Great Western broad gage line, of Brunel, was a magnificent road, built at an appalling cost per mile.

With the exception of those which were built in the more populous States bordering on the Atlantic seaboard, the early railroads of America have had to do pioneer work. In Europe the railroad followed the population, and was the result of it. In America the population followed the railroad, which in some cases has been pushed out a thousand miles ahead of the onrolling wave of emigration. These conditions, coupled with the natural freedom of the American engineer from the restraints of tradition, and his tendency to work out any problem from its own proper point of view, have given us the American railroad of to-day.

In the first place the engineer dared to believe that a locomotive could climb a hill and swing round a curve—Mr. Brunel and his associates notwithstanding. So when the locating engineer came to a hill he preferred to go round rather than tunnel through it; and, if that was impossible, he carried his line over it, skillfully adjusting his survey to the topography of the country, and keeping the grade within the desired limit. Where one or two feet in a hundred had been considered the practicable limit of grade, he did not hesitate to use three and four; and where four and five degrees was the limit of curvature in Europe, he boldly ran in eight and ten degree curves, and on certain lines in later years increased this to sixteen and even twenty degrees! When this undulating and sinuous roadbed had been graded, and it came to the question of laying upon it the costly rails, ties and ballast the "coat was" again "cut according to the cloth," and, in obedience to an imperative economy, these items were cut down to the lowest practicable limit. And here it was that the mechanical engineer stepped in, and with rare ingenuity produced a locomotive and cars that were admirably adapted to travel upon track that was neither level, nor straight, nor smooth in its running. The swiveling truck solved the problem of the curves, the coupled driving wheels and heavy engines the problem of the grades, and the equalizing levers smoothed out the inequalities of the track. And thus it was that, in the adaptation of the track to the country and of the locomotive and cars to the track, the civil and mechanical engineer made possible the enormous development which has characterized the past half century of railroad building in the United States. Had they attempted to build as Brunel built the Great Western road in England, the development of the vast internal resources of the country would have been thrown back a whole generation.

In speaking thus of the early American roadbed, it is not intended to imply that the best American track of 1896 is one whit inferior to that of contemporaneous European railroads, for its improvement has generally kept pace with the increase of the traffic which passed over it, until to-day it is safe to say that the main lines of such roads as the New York Central, the Pennsylvania, the New Haven, and other leading companies, is as fine, and in some respects better, than the best to be found in Europe.

As we look at the railroad map of the United States

THE MERCHANTS' BRIDGE, ST. LOUIS—TYPICAL MODERN DOUBLE TRACK STEEL RAILROAD BRIDGE.

Three spans, 517 feet 6 inches, and six spans, 125 feet long.

for 1896, with its 181,082 miles of track spread out like a finely meshed network over the face of the country, it is difficult to realize that at the date of the foundation of the SCIENTIFIC AMERICAN there were less than 5,000 miles of track in the whole of the States, and that this represented a few small, disconnected lines, scattered through the Atlantic and Southern States, and a few fragmentary systems in the Middle States. Such roads as there were had been laid out with reference to the existing lines of transportation by road and river, and were largely supplementary to them. The Eastern roads were only just beginning to reach across the Alleghenies into the valley of the Mississippi; and as yet there was no sign of a through trunk line to the West, although several lines connected New York with Washington and other important points. It is interesting to note in passing that the stimulating effect of the new upon the old methods of transportation was seen in the rapid development of the river steamboat, which at this early period was far in advance of the ocean steamer, both in speed and accommodation.

Viewed in the light of its subsequent development, the railroad system of 1846 appears both disjointed and insignificant. In that year there were but 4,930 miles in the whole United States; in 1847, 5,598 miles; in 1848, 5,996 miles; in 1849, 7,365 miles; and in 1850, 9,021 miles. In the next decade some 20,000 miles were added, the total reaching 29,739 miles in 1860. Then came the blight of the war, the construction during the next five years averaging only 651 miles a year, and bringing the total up to 32,996 miles in 1865.

THE ST. LOUIS BRIDGE AFTER THE GREAT STORM OF MAY 27, SHOWING INJURY TO STONE WORK ONLY.

At the close of the war, however, the nation devoted its energies and capital to the development of the vast natural resources of the country. One of the first and most important results of this industrial activity was the completion, on May 10, 1869, of the first continuous transcontinental road across America. This event, coupled with the consolidation about this time of the Hudson River and the New York Central Railroads, forming a trunk line to the West from New York City, marked the opening of a new era in the development of the American railroad. From that time on the growth was simply phenomenal, the total mileage increasing in 1876 to 74,100 miles; in 1886, to 133,606 miles; and in 1896, to 181,082 miles! Subsequent to the completion of the Union Pacific, the Southern Pacific Company gave the country, in 1882, another transcontinental route, by way of New Orleans; the Atchison, Topeka, and Santa Fe Company completed a Pacific coast connection through the belt of country lying between the Southern Pacific and the Union Pacific systems; the driving of the golden spike of the Northern Pacific Railroad in August, 1883, opened up the vast forests and wheat fields of the Northwest; and on June 18, 1893, the Great Northern, the latest of the transcontinental roads, dispatched its first through train to Seattle, on the Pacific coast.

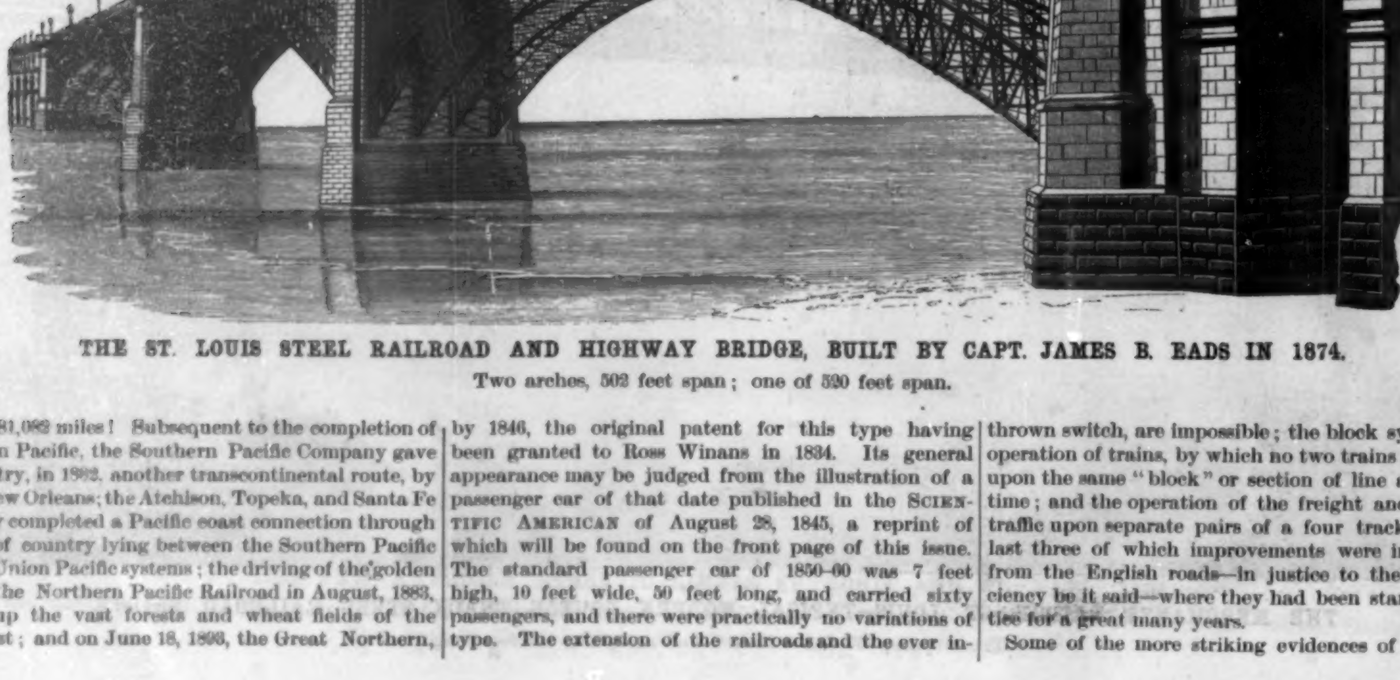
Thus was built up the most stupendous system of transportation in the world, with its 181,082 miles of track. An impressive sense of its magnitude is conveyed in the statement that its rails, if strung out in a single continuous line, could be wrapped around the earth fifteen times, with many a mile to spare!

With the growth of population and manufactures, and the consequent increase in dividends, there came a steady improvement of the roadbed and rolling stock. The introduction of Bessemer steel rails, with their increased stiffness and durability, produced a marked change in the character of the track. The old pear-shaped iron rail, of 40 to 50 pounds weight, was succeeded by the steel headed rail, and this gave place to the 75 pound steel rail of the last, and this in turn to the 100 pound steel rail of the present, decade. Greater attention was paid to ballasting and draining the roadbed, and as fast as the dividends of the company would allow, the lines were revised, the curvature and grades being reduced, and distances shortened by means of costly bridges and tunnels.

The typical American passenger car, with its long body carried upon end trucks, was well established by 1846, the original patent for this type having been granted to Ross Winans in 1834. Its general appearance may be judged from the illustration of a passenger car of that date published in the SCIENTIFIC AMERICAN of August 28, 1845, a reprint of which will be found on the front page of this issue. The standard passenger car of 1850-60 was 7 feet high, 10 feet wide, 50 feet long, and carried sixty passengers, and there were practically no variations of type. The extension of the railroads and the ever increasing length of the journeys called for special provisions for the comfort of the passengers; and in 1864, after several abortive attempts by various roads to produce a comfortable and popular sleeping car, Mr. Pullman brought out his first sleeper, the celebrated Pioneer. The success of this venture led to the formation, in 1867, of the powerful Pullman company, and under their management the sleeping car has developed to its present size and splendor. In 1887 Mr. Pullman patented the vestibule, a flexible diaphragm, which connects the ends of adjacent cars, keeping out the noise, dust, and cinders, and imparting a remarkable steadiness to the whole of the train. Steam heat has replaced the uncertain stove, and gas and the electric light the oil lamp; and what with parlor cars and observation cars, bath rooms and barber shops, and a host of conveniences that minister to one's ease and recreation, the five-day trip from the Atlantic to the Pacific may now be performed amid the multiplied comforts of a first-class city hotel.

Restrictions of space forbid more than a passing reference to the development of the many appliances designed to promote safety of travel. By far the most important of these was the continuous automatic air brake, designed by George Westinghouse, Jr., in 1868, in which year it was first practically applied on trunk roads. In this system, as finally modified, by means of a small lever, placed conveniently to hand, the engineer can instantly apply the brakes on every car, and should the train break apart, the brakes will set themselves automatically. The simplicity, certainty, and power of this brake are remarkable, and render it one of the most successful and life saving inventions of the age. In the celebrated Burlington brake trials in 1886-87 a train of fifty cars, a third of a mile long, running at forty miles an hour, was stopped in a third of its own length. Scarcely less important was the introduction of the Miller platform and coupler in 1863, and the Janney coupler, with many others at a later date; automatic signaling; the interlocking system of levers, whereby a contradictory signal, or an accident from a wrongly thrown switch, are impossible; the block system in the operation of trains, by which no two trains are allowed upon the same "block" or section of line at the same time; and the operation of the freight and passenger traffic upon separate pairs of a four track road; the last three of which improvements were importations from the English roads—in justice to their high efficiency be it said—where they had been standard practice for a great many years.

Some of the more striking evidences of progress in



THE ST. LOUIS STEEL RAILROAD AND HIGHWAY BRIDGE, BUILT BY CAPT. JAMES B. EADS IN 1874.

Two arches, 502 feet span; one of 520 feet span.

the past twenty years are gathered for comparison in the accompanying table:

	1876.	1896.
Mileage	74,100	181,082
Invested capital	$4,658,000,000	$11,565,000,000
Earnings (gross)	503,000,000	1,100,000 000
Number of locomotives	15,000	36,300
Weight of locomotives	30 to 50 tons	65 to 100 tons
Number of passenger cars	14,000	35,700
Weight of passenger cars	20 to 30 tons	30 to 50 tons
Number of freight cars	384,000	1,210,000
Capacity of freight cars	10 to 12 tons	30 to 40 tons
Speed of passenger trains	20 to 25 miles	40 to 50 miles
Number of employes	370,500	850,000

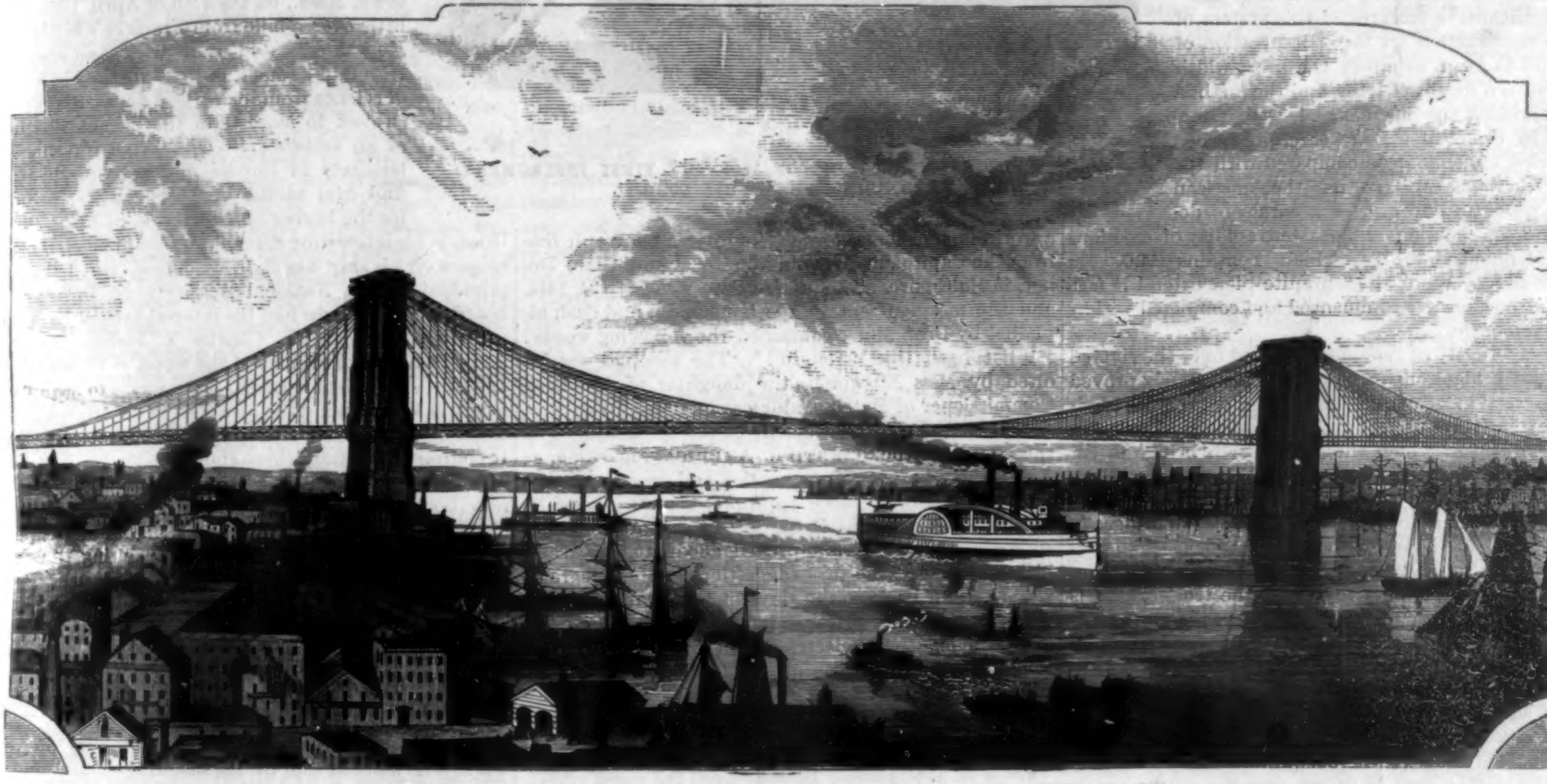
THE AMERICAN RAILROAD BRIDGE.

The deep canyons and ravines of the mountain passes, and the broad rivers of the plains, have necessitated the construction of a vast number of difficult and costly bridges as the railroads were gradually spread out over the country. Fifty years ago bridges were built almost entirely of wood, and the phenomenal growth of the railroad system was rendered possible by the abundant supply of suitable timber, and the free use of it in the form of pile and bent trestles, and what is known as the Howe truss bridge. The latter bridge, patented in 1840 by Mr. Howe, was for years the standard railroad bridge of America: and it is still doing excellent service in the West, where the magnificent pine and fir timber furnishes sticks of a size and quality that makes it possible to build this form of truss in spans of remarkable length and stiffness. On the lines of the Southern Pacific Railroad, in Oregon, there are to-day modified Howe trusses of wood, from 200 to 250 feet in span, which are carrying the heaviest engines and trains, and giving excellent service. The chords and braces of this form of truss are of timber, and the ties, which are vertical, are of round iron, with screwed upset ends, secured with nuts on the outer faces of the top and bottom chords. The braces are square ended, and bedded upon cast iron angle blocks, which rest upon the chords at the panel points. The excellence of this truss consisted in its simplicity, strength, cheapness, and ease of construction and erection. When the tie rods and small screw bolts were once delivered on the ground, the cross cut saw, the ax and the adz did the rest; and when saw mills were not available, the sticks could often be hewn from the standing timber on each side of the track—as was frequently done in crossing the Rocky and Cascade Mountains of the West—and framed and erected on the spot. The wooden Howe truss has been a potent factor in the development of the American railroad, and it anticipated by more than a generation the advent of the iron and steel truss.

The Pratt truss, with vertical posts and inclined ties, patented in 1844, has become, in its various modifications, in the later age of steel construction, the prevailing national type.

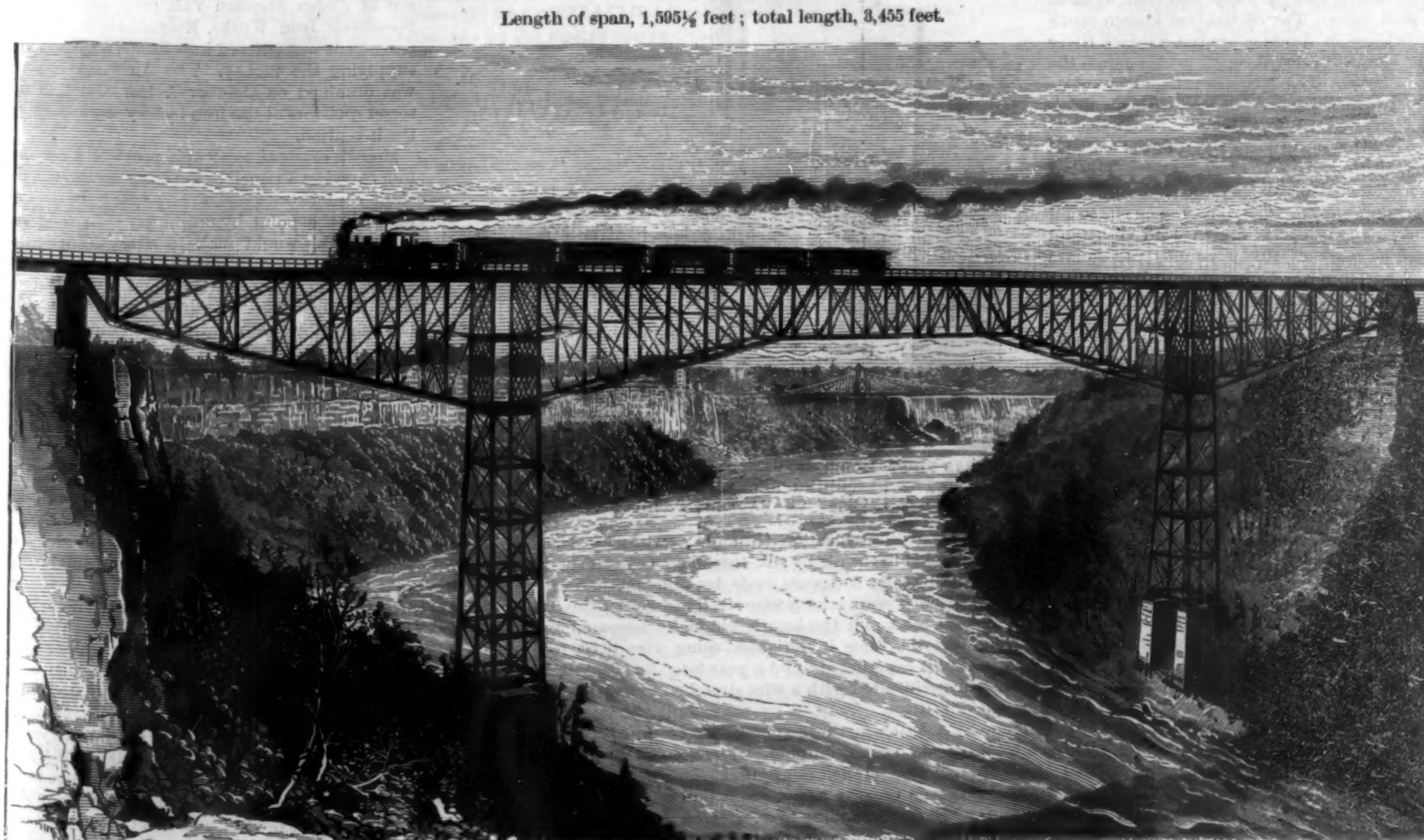
In 1846, Frederick Harbach patented an iron Howe truss, with cast iron top chord and braces, and wrought iron bottom chord and ties, and from that time on, during the next twenty years, a large variety of more or less useful trusses were introduced, conspicuous among which were the Whipple, the Bollman, the Fink, and the Post trusses.

Mr. J. H. Linville was the first engineer to introduce the typical long span railroad truss in America. His famous iron bridge over the Ohio, at Steubenville, in 1864, was followed in 1872 by the Cincinnati bridge of 420 feet span. To Mr. C. Shaler Smith belongs the credit of designing in 1876 the first long iron cantilever bridge, known as the Kentucky River bridge, which consisted of three spans of 375 feet. On July 4, 1874, the famous St. Louis arched bridge of Captain James B. Eads was opened. The great size of the arches—two of 502 and one of 520 feet span; the novel method of their erection—the arches being built out simultaneously from the piers, to which they were tied with temporary guy ropes; the daring but successful use of the pneumatic caisson for the deep foundations (107 feet below M. W. L.) of the piers; together with the original and admirable design of the trussed arches of the bridge—all conspired to mark this as one of the most brilliant feats of engineering that the world has ever



SUSPENSION BRIDGE OVER THE EAST RIVER, AT NEW YORK.

Length of span, 1,595½ feet; total length, 3,455 feet.



THE STEEL CANTILEVER RAILROAD BRIDGE OVER NIAGARA RIVER.

Length of span, 470 feet; total length, 910½ feet; height, water to rail base, 239 feet.

seen. The destructive tornado of May 27, which tore asunder and scattered the massive masonry of the approaches to this bridge, failed to disturb the equilibrium of the steel arches themselves; and no finer tribute was ever paid to the skill of the bridge engineer than is offered in the photographic reproduction which we present on another page.

The scientific methods of bridge design and construction adopted by Captain Eads have been elaborated by subsequent engineers, until bridge designing is to-day perhaps the most exact branch of the engineering profession. The calculation of the strains in steel trusses is now a matter of mathematical certainty and precision. The various erratic forms of trusses have fallen into disuse, and a standard type of great excellence has survived, one of the latest examples of which is shown in the engraving on another page of the Merchants' Railroad Bridge at St. Louis, built in 1890 by the Union Bridge Company, of New York. The Merchants' bridge comprises three main spans, 517 feet 6 inches long, and six deck spans of 125 feet. The trusses are built entirely of steel and are pin connected, the tension members being steel eye bars, and the compression members consisting of built-up lattice posts and chords. The floor beams and stringers are plate steel girders, the latter being riveted at their ends to the bottom of the posts and vertical ties.

The distinctive features of this system of bridge construction are the concentration of material in large members, the great width of panel and height of truss, and the method of connecting the members at each panel point by means of a large, carefully turned and fitted steel pin. As compared with the European practice of riveting, the American practice conduces to greater accuracy of design and construction, and greater rapidity of erection. The Merchants' bridge, which contains 11,000,000 pounds of steel, and whose granite piers extend 70 feet below the water, was commenced and completed within thirteen months.

The superiority of the pin-connected over the riveted system of bridge construction has been clearly proved in the erection of cantilever bridges, a type which is now extensively used by American and European builders, and of which the great Forth bridge of Sir Benjamin Baker, with its two 1,710 foot spans, is the most monumental example. In its simpler forms, the cantilever is exceedingly ancient. There are bridges in China which are hoary with age whose construction is based upon this principle. The most valuable feature of the cantilever, as compared with the truss bridge, is the facility with which it lends itself to the crossing of rivers and ravines, where the depth of water or other natural features render it impossible to erect any temporary falsework. Perhaps the most notable early use of the cantilever system of erection in America was seen in the building of the above mentioned Eads bridge at St. Louis, where equilibrating portions of the steel arches were built out simultaneously on each side of the piers and tied back to them with steel ropes. Two of the best known cantilever bridges in America are the Niagara River bridge and the Poughkeepsie bridge across the Hudson River. The Niagara bridge has a clear span between towers of 470 feet, with an intermediate truss 120 feet long. Poughkeepsie bridge has three cantilever spans of 548 feet and two connecting spans of 525 feet each. The latter were erected by the aid of falsework, and the cantilevers were then built out in the usual manner. The bridge is designed to withstand a wind pressure of thirty pounds per square foot of surface, and to carry a uniform train load of 3,000 pounds per foot on each track, preceded by two 85 ton locomotives.

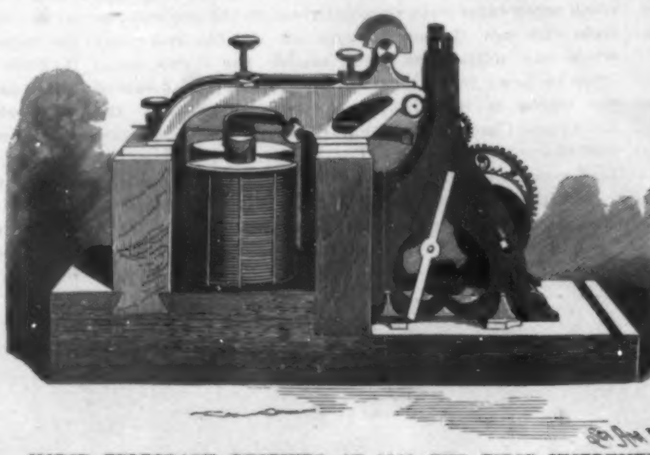
No treatise on American bridge building, however brief it may be, can fail to make mention of the development of the wire suspension bridge. Among many other notable bridges of this type are the Niagara suspension bridge, of 821 feet span, the Covington and Cincinnati bridge, of 1,057 feet span, and the Allegheny bridge, with its two spans of 344 feet, all of which were designed by that gifted engineer, the late John A. Roebling, who subsequently raised an enduring monument to his genius in the design and erection of the great East River bridge, uniting the cities of New York and Brooklyn.

This noble structure is too familiar to call for more than a recapitulation of its leading features. The main span is 1,595½ feet long, and the total length, with the approaches, is 3,455 feet. The foundations for the towers were carried down 78 feet below high water by the pneumatic process, and the towers themselves extend 272 feet above high water, making a total height, from foundation to capstone, of 350 feet. The four cables, 15 inches in diameter, are of steel wires laid parallel and wrapped. The floor of the bridge is stiffened with four steel trusses, and carries two carriageways, two standard railway tracks and one footway. The trains are operated by a steel cable, and they carry an immense traffic, the total in 1894 amounting to 43,000,000.

Great as are the proportions of this bridge, it is likely, before long, to be surpassed by the proposed railroad bridge across the Hudson River, at New York, which is to have a main span of 3,254 feet, carried on twelve steel wire cables, 23 inches in diameter. The suspension towers, which will be built of steel plates and angles, will reach to a height of 587 feet above the water. It is not too much to say that this bridge, which is to carry six railroad tracks, side by side, will be the noblest constructive feat of any age or clime.

THE TELEGRAPH.

Fifty-two years and two months have passed since a world famous message was sent over a telegraph line from the Capitol, at Washington, to Mount Clare Depot, in Baltimore. The precise date was May 24, 1844, and the message sent in the famous dot and dash alphabet by Prof. Morse contained the following words: "What hath God wrought!" The message was indited by Miss Ellsworth, the daughter of the then Commissioner of Patents, and was intended to express the wonder of the achievement of the telegraph. For this edition of the SCIENTIFIC AMERICAN, marking, as it does, fifty years of the invention and progress of the scientific world, no more appropriate motto could be chosen, for it seems as if the last fifty years definitely showed man's powers and proved adequate to measure his ability. For the first suggestions of the telegraph we can go far back to the days of Otto van Guericke, whose experiments of transmitting through a conductor an ell in length an electric disturbance from his frictional machine with its globe of sulphur excited by rubbing against the hand is well known.



MORSE TELEGRAPH RECEIVER OF 1844—THE FIRST INSTRUMENT RECORDING THE MORSE CODE.

Coming down later, however, we find attempts directly made in the line of telegraphy. In 1727, Stephen Gray, of the Charter House, London, transmitted electrification through a wire 700 feet, suspended in the air by silk threads. Other experiments of the same sort were made by different investigators. Twenty years later a wire stretched across the Thames was used, and the length gradually increased until we find the same investigator using wire 10,600 feet long in his experiments, and a year later Benjamin Franklin experimented with a wire stretched across the Schuylkill River.

MORSE FIRST MODEL—PENDULUM INSTRUMENT OF 1837, SHOWING THE RECORDING RECEIVER (1), PORTRULE (2), TYPE (3), AND EXAMPLE OF CHARACTERS PRODUCED (4 and 5).

A letter in the Scot's Magazine in 1753, signed by C. M., suggests an electric telegram operated by a frictional electrical machine; and in 1774, at Geneva, Lesage erected a telegraph line of 24 insulated wires, each corresponding to a letter of the alphabet. Many other attempts were made and signals were transmitted by static excitation produced by frictional machines. At the beginning of the present century the voltaic battery was invented. The investigators had at once an instrumentality for maintaining a current through a wire, by which the decomposition of water could be brought about, magnets attracted and other phenomena produced, and, in 1808, the Munich Academy of Science received from Sommering a communication describing a telegraph containing thirty-five wires, one for each letter of the alphabet and one for each number. At the transmitting end arrangements were provided for passing currents through any one of the wires. At the receiving end the electros were immersed in acid, and, completing the circuit, caused the evolution of bubbles of hydrogen. Each tube corresponded to a letter or a number.

Passing by many other attempts, we find, in 1839, the Wheatstone telegraph, fairly effectual, producing its signal by means of what are practically galvanometer needles. A bell alarm was used to call the operator. To produce a powerful enough sound, Wheatstone used a relay circuit, the first one in the history of the art. Henry, in 1832, had, as one result of his experiments in electricity, used the electric magnet in a signaling telegraph, and for him is claimed the glory of being the inventor of the first electro-magnetic telegraph.

Samuel F. B. Morse was born in Charlestown, Mass., on the 27th of April, 1791, but a little over a mile from Franklin's birthplace. He was educated as an artist, and won high triumphs as such, but was marked as a lover of science from his earliest days. His life was subject to more than the usual vicissitudes of an artist's existence. After traveling extensively in Europe and studying there, we find him sailing on the packet ship Sully, for the harbor of New York, in 1832. Philip Hone, in his interesting diary, states that among the passengers on his ship was S. F. B. Morse, the artist and president of the National Academy of Design. On board the ship Morse had his interest excited by a conversation in which Dr. Charles T. Jackson was the leader, who spoke of some of the wonders of electricity and of the electrical magnet. This seems to have fixed firmly in Morse's mind the idea that an electric telegraph could be constructed with the electric magnet as a basis. It engrossed his mind throughout the voyage, and during the six weeks which it lasted he jotted down in his note book different sketches of a proposed system of electrical telegraphy. He practiced his art and experimented with the telegraph, the latter, during the next few years, gradually wooing him from his brush. Prof. Daniel, of London, in 1835 invented the constant current battery, which proved a powerful adjunct to Morse's work. He was confronted at once with the difficulty that the current became enfeebled on too long a line, and used the relay circuit to overcome this trouble. In 1837 he explained his invention to Prof. Leonard D. Gale, of the University of the City of New York, who assisted him by his scientific counsel, and in the same year he interested in it Alfred Vail, a son of Judge Stephen Vail, proprietor of the Speedwell Iron Works, Morristown, N. J. An agreement was entered into between them, Vail supplying the money. The American patent was obtained on October 3, 1837, and Vail in secret quarters at the iron factory worked upon the invention.

Morse's original telegraph provided a pendulum carrying a pencil or marking device in constant contact with a strip of paper to be drawn beneath the point by machinery. As long as inactive, this would make a straight line upon the paper. The pendulum carried also an armature, and an electric magnet was placed near the armature. A current passed through the magnet would draw the pendulum to one side. On being released the pendulum would return, and in this way any amount of zigzag marks could be made on the paper as it traveled with the pencil constantly pressing upon it. Vail made some changes in the device and substituted for the pendulum and marking pencil the familiar lever with pencil of the more modern type of Morse machine, and substituted for the zigzag line the dot and dash alphabet.

In 1839 Morse began the hardest period of his life. He was dependent for his living upon what he could earn as a professor of art. At one time he went twenty-four hours without food. Toward the close of 1841, he writes that he has not a cent in the world, but affirms that he will not run in debt. In the next year he submerged in the New York Harbor between Castle Garden and Governor's Island a wire which he had insulated and sent signals through it. The experiments were repeated at Washington in a canal, in December of the same year, and Morse, in describing his experiments in 1844, announced his belief that signals could and would be sent across the Atlantic Ocean by electromagnetic telegraph. Sick, and tired at heart, agitating for an appropriation from Congress to test his invention, Morse found himself in December, 1842, with his personal funds reduced

to 37 cents and feeling ready to abandon the whole subject indefinitely. Aid from the government was at hand, however, and a bill recommending the appropriation of $30,000 in aid of the telegraph was passed by Congress.

Soon after this work was begun on a line between Baltimore and Washington, and among those concerned in its erection was Ezra Cornell, the founder of the Cornell University. An attempt was made to lay the wire underground, and after an expenditure of nearly all the appropriation, this plan was abandoned and an aerial line was started. In seven weeks the work was completed, and the famous message was sent. It was written upon a strip of paper with an embossing point which simply indented the paper with dots and dashes.

Morse had conceived the idea of the relay circuit and had used in the early telegraphs a relay either as an extension of the line or as a local circuit. His great idea was to produce marks making a record of every message sent, and this idea seems to have been at the base of his work. One of his troubles consisted in accurately opening and closing the circuit in order to produce his alphabet. He used metallic type for the purpose with indented faces so shaped as to open and close the circuit at proper times and for proper periods, for the production of the desired markings. Each letter constituted a separate type, which was mounted on a portrule. When this was filled with type representing the message, it was drawn under the contact point. Then, as a simplification of this, two contact points close together were used, between which a wedge was thrust by hand, so as to open and close the circuit. Again, a keyboard was devised with a separate key like a piano, for each letter, but eventually, about 1844, the plain key, such as used to-day, was adopted. After the sending of the famous message in 1844, on April 1, 1845, the line between Baltimore and Washington was opened for public business under the auspices of the Post Office. One cent for every four characters was charged, and during the first four days one cent was received. After a week the receipts had risen to one dollar. Telegraph lines were slowly put up, but in 1846 the system was still experimental. In 1845 New York and Philadelphia were connected, in 1846 Philadelphia and Baltimore were connected. The government had rejected the purchasing of the Morse invention, so everything had to be done by private enterprise. The first ten years following 1846 were devoted to the exploitation of the new invention, and gradually more and more lines were added until, in 1856, what has been described as a straggling web of lines under the control of thirty [illegible] rival companies, working different apparatus under different patents, covered the more populous area of the country. Dividends were not paid except by one or two of the companies, and the prospects were anything but bright.

During these ten years inventors had not been idle. Morse's system required but little; the relay, the hand key and the alphabet and mechanism for reproducing the alphabet were all in existence in 1846, and since then little has been done with the Morse system proper in the way of addition. In the way of suppression the most important thing of all has been done. Various marking devices had been tried — pencil, embossing point, pen and inking wheel. Morse's apparatus was adapted for any of these devices, but after a while the clerks and attendants on instruments learned to read them by the sound made by the marking lever, and, in spite of threats of instant dismissal, they persisted in doing so when not watched. Morse was violently opposed to it, naturally regarding the recording device as the very soul of his instrument. Vail, who throughout figures as the entirely disinterested, self-sacrificing coadjutor of Morse, and who by many is considered as much the inventor of the Morse system as Morse himself, was the first to yield and devise, by simple suppression of parts, the well known sounder, converting the Morse telegraph into an acoustic one.

Other inventors took the subject in hand, all basing their work for the most part on the production of a record. Bain used chemical decomposition to produce a stain from a piece of paper, which, running in dots and dashes, would convey a message. To produce the dots and dashes he used a long strip of paper, previously perforated, which was drawn between two contact points. A short perforation produced a stain upon a corresponding strip of paper, giving a dot, while a long perforation produced a dash. Over and over again these devices have been applied in the most highly developed rapid transmission apparatus of the present day. Royal House devoted his energies to the development of a printing telegraph, but was estopped by Morse from the use of a relay. He performed the heavy work of his printing apparatus by pneumatic power, which was simply controlled by the telegraph line, and most curiously, in his attempt to produce a sensitive sounder, he described in one of his patents, long antedating Bell's invention, what is to all intents and purposes a Bell telephone, only he never imagined for a moment that it could be made to speak, and the microphone was still lacking to make it a practical invention.

We have seen that the early Baltimore and Washington line had Ezra Cornell as one of its constructors. In 1856 the amalgamation of the many companies then in existence was proposed and carried out through the agency of Hiram Sibley, the founder of the Sibley School of Science at Cornell University. Thus we find this great university intimately connected with the early days of the telegraph. The scheme was termed a crazy one; it was said to be like collecting all the paupers in the State and arranging them into a union so as to make rich men of them; but it was done.

The records of the business of the Western Union, originally so named because it was intended to be a union of Western telegraph companies, have been tabulated since 1867. It had, in that year, 46,270 miles of poles and cables and 85,291 miles of wire were in use; and 5,879,282 messages were transmitted. The receipts were $6,568,925.36. Its profits were $2,624,919.73. In 1895, with 189,714 miles of poles and cables, and 802,651 miles of wire, with 58,307,315 messages sent, receipts of $22,218,-019.18 were shown, with a profit of $6,141,389.21. Since 1868 the average tolls per message had fallen from $1.047 to $0.307 per message. The Western Union represents about seven-eighths of the business of the United States, and by its wires, cables and connections any part of the world can be reached. Next to it in importance comes the other great American company—the Postal Telegraph. This and the Western Union do almost all the telegraphic business of the United States.

It would be too great a task to attempt to catalogue, much less describe, the many inventions in telegraphy. The genius of Edison, Delaney, Stearns and others has made it possible to send a number of messages simultaneously in both directions on the same wire. The British Postmaster-General states in a recent report that on a line on which in 1870 the highest speed by Wheatstone automatic was 60 to 80 words a minute, 600 words a minute is now possible. The old Bain principle of electric decomposition and the use of a perforated ribbon drawn between contact points to produce the dot and dash making contacts have reappeared in various instruments. Even the old Morse pendulum, giving its zigzag line, is the prototype of the siphon recorder used in ocean telegraphy.

Construction is receiving more and more attention. The Western Union Company are putting in hard drawn copper wire in place of iron on trunk lines, with the most satisfactory results. Over 10,000 miles of such wire is now in use. It relieves the strain on the poles, owing to its lightness, and its electrical superiority makes it work under very adverse meteorological conditions.

In the production of current, dynamos have been in some cases substituted for batteries with the best results. Time service is carried on throughout the United States from the Washington Naval Observatory. The telegraph business in this country, in spite of the sparsely settled districts and long distances of transmission, is made to show a profit. In England, where it is run by the government, and where it is calculated that of 70,000,000 messages per annum, some two-thirds are sent from or to London, a large annual deficit is shown.

PHYSICS.

Fifty years ago the science of physics was in a very peculiar condition. Mayer, about 1842, and Joule, 1843-1845, had given to the world their determinations of the mechanical equivalent of heat, laying the corner stone of the entire structure of modern physics. An immense amount of other data had been determined by methods which were hampered by inevitable inaccuracies, but which were accepted and utilized to the utmost by scientists of those days. In one point of theory hopeless confusion existed, on account of the want of an adequate distinction between force and energy. Physicists had gradually acquired the doctrine of the indestructibility of energy, and it was expressed in the so-called doctrine of the conservation of force. This supposed law was promulgated as one of the great triumphs of science, but it was not satisfactory. The comments of scientists upon it and their troubles in trying to reconcile facts with it make curious reading to-day when we know that force can be created and annihilated at will, and when we have learned to distinguish definitely between force and energy. After years of work the distinction was formulated and a threefold system of units was established for physics; the members of the system were force, work and energy. They were definitely distinguished, one from the other, and at once the great doctrine of the conservation of energy, unproved as it may be, obtained universal acceptance by men of science, and to-day is universally used as a working hypothesis. Faraday was one of those who had trouble with the doctrine of the conservation of force. He was an intimate friend of Clerk Maxwell, and utilized the mathematical genius of his friend in his work, and it was Maxwell who, working on the theory of dimensions, did much to definitely fix the relations of force, work and energy in all the formulæ of physical units which have sprung from the theory in question. It is impossible to dwell too strongly on this point in the development of physics during the last fifty years. Until force was accurately distinguished from energy the doctrine of the conservation of energy could not be utilized, and it is precisely on this doctrine that the whole of modern physics is constructed. It would be fair to term the theory the greatest discovery of the century in physics. The theory of dimensions is a necessary comment upon it, putting it into precise shape with due results.

The battle between the undulatory and the corpuscular theories of light had waged hotly, Newton and Young being the rival authorities appealed to, but the last fifty years have seen the undulatory theory universally accepted, and, in connection therewith, have seen the theory of electricity based on the luminiferous ether and its disturbances also accepted. Light and electricity thus were brought into near relations with each other, and a sort of conviction was established that no substance transparent to light could be a conductor of the electric current—something remarkably verified by the allotropic forms of carbon. Again we find the name of Clerk Maxwell, the developer of the electro-magnetic theory of light, foremost in the work of establishing the unity of natural science.

In 1850 Fizeau announced the success of his determination of the velocity of light by a physical test, using his rotating mirror to displace the apparent reflection of an electric spark. His results were close to the truth, and subsequent determinations by astronomical as well as by physical methods have but slightly affected them.

Mayer and Joule had developed the modern theory of heat, so that during the last fifty years comparatively little of basic work was possible. Melloni's work on what was called radiant heat, which comes nearly within our period, is an interesting example of old methods. The identification of this "radiant heat" with light phenomena is a direct growth of a recent period. Now it is treated as a particular phase of ether waves and the term itself is rejected. If the ether waves are long enough, they produce "obscure light," if the expression may be allowed, the old radiant heat. If of a certain range of length, the optic nerve is affected and light is produced. If still shorter, they cease to affect it again. Light becomes a subjective phenomenon, treated under the subject of ether waves. Chevreul's monumental work on color phenomena belongs to the light-producing division of ether waves, largely in the order of subjective phenomena.

Sound has been the subject of extensive research, Helmholtz's analysis of the physiological basis of music, published in 1862, marking perhaps the greatest epoch in the recent development of the subject. Mathematics, physiology and experiment were all devoted to the accomplishment of his great task, and the effect of overtones in giving its distinguishing quality to a note was formulated. By the use of a telescoping resonator Helmholtz succeeded in determining precisely what overtones existed in any given sound, and then by producing simultaneously the fundamental and overtones previously determined he reproduced mechanically the sound in question. This gave the analysis and synthesis of a sound. Koenig may be cited as a developer of apparatus for such study, some of his acoustic apparatus being a true scientific triumph.

Faraday's work has done much to elucidate the physics of electricity, and the magneto-generator of currents and the electric motor were natural sequences thereof. Physicists developed the subject and constructed motors with electro-magnetic fields, until gradually the conception of a self-exciting dynamo arose, and soon currents of high intensity began to be produced by self-contained generators. Then came the greatest discovery of all, that a machine adequate in its revolutions to generate a current would, if a current were passed into it from an outside source, generate mechanical energy. This convertibility of the dynamo into a motor was a beautiful sequence of the doctrine of the conservation of energy, and at once enabled us to convert mechanical energy into electrical energy and vice versa.

Spectrum analysis is justly considered an achievement in physics, and in the hands of astronomers it has led to the discovery of double stars and the determination of the velocity of the motions of stars receding from or approaching to the earth. Helium was, in 1872, announced as a probable constituent of the sun from lines in its spectrum. Recently Ramsay has identified it in the gas given off with argon from the mineral cleveite.

The discovery of argon, as the result of a physical investigation, is one of the triumphs of modern science. It was found by Rayleigh and Ramsay that nitrogen gas from the atmosphere was of higher specific gravity than that from chemical compounds. The hitherto unknown constituent of the air, argon, was discovered and a new element was added to the list, an element which mankind had been breathing unsuspectedly for all time. The acuteness of the millionaire scientist of the last century, Cavendish, is shown in his paper on nitrogen, in which it is almost certain that he describes the discovery of argon. He only dared to suggest the existence of any such gas; his suggestions slumbered for over a century.

The work done by the different scientists in physics during the last years is too vast to bear repetition. Every branch of the subject has been worked up to the highest state of development; throughout every phase of investigation the definite mathematical relations of physical units, of time, space, force, work, energy and others, appear as the guides. The physicist has worked

MEN OF PROGRESS — AMERICAN INVENTORS.

n spectroscopic analysis with most brilliant results. angley's classic results with the bolometer in the in-sible infra-red spectrum being worthy of citation as example of the requirements of modern physical sts. In the same line Michelson worked in the ob-aining of a scientific unit of length by using the wave ngth of specified light, and this is a wonderful illustra-on of the refinement of physical methods. The old time stinction of vapor and permanent gas has ceased to xist, as all the gases have yielded to the experimenter nd have been liquefied, and, in many cases, solidified. rookes discovering peculiar phenomena in gases at ery high degrees of exhaustion endeavored to prove the existence of a fourth state of matter, adding one to the long accepted division. While his researches have not definitely established this fact, they have led the way to the most recent of the discoveries of phys-ics, "last of all the greatest," the X ray phenomenon discovered by Roentgen, a name that will go down to posterity with that of Newton, Faraday and Maxwell.

MEN OF PROGRESS.

On the opposite page we present a reproduction of the large engraving, "Men of Progress—American Inventors," a fine steel engraving which was published by Munn & Company. The original oil painting from which the engraving was made was painted by C. Schussele in Philadelphia, in 1861. It was engraved on steel by John Sartain, a Nestor of American engravers. It is a fine example of the perfection to which steel engraving has been brought at the period in which it attained its highest development. In thousands of homes to-day this superb engraving still ornaments the walls.

On the left of the engraving is Dr. Morton (1819–1868), a dentist, who first used ether as an anæsthetic in 1846. From this dates the introduction into surgery of ethereal anæsthesia; next to him is James Bogardus (1800–1874), whose numerous inventions include a ring spinner, an engraving machine and the first dry gas meter. He was also interested in building iron buildings, and was one of the fathers of the modern system of iron construction. Col. Colt (1814–1862), the inventor of the Colt revolver, who is next to him, is referred to elsewhere in the more extended biographical notices, as is also Cyrus McCormick, the father of the reaper, who is at his right. Behind is Joseph Saxton (1799–1873), who devised ingenious mint machinery and coast survey and meteorological instruments.

Charles Goodyear (1800–1860), who is seated at the table, immortalized himself as the inventor of the process of vulcanization of rubber, which he patented in 1844. Behind him stands Peter Cooper (1791–1883), who is widely known for his varied talents and many inventions and for the success he met with in the development of the glue industry in this country. He was interested also in various iron works which he successfully exploited. His name will always be remembered as a philanthropist, for he founded and endowed Cooper Union in New York. Seated at the table is Jordan L. Mott, who will be remembered for his works in iron, fuel, etc. Leaning on one side of the pillar is Prof. Joseph Henry (1797–1878). He was an American physicist, especially noted for his investigations in electro-magnetism. On the right of the center is Dr. Eliphalet Nott, who made important researches on the management of heat. Behind is Capt. John Ericsson, of whom a more extended account is given on another page. In front is Sickles, who invented a steam cut-off. Seated in a chair is Prof. Morse, who is perhaps the most imposing figure in this unique collection of American inventors. His portrait and a biographical sketch may be found in another page. Behind is Henry Burden (1791–1871), a Scotch-American inventor. His inventions include a cultivator (1820), the hook-headed railroad spike, and a machine for making horseshoes. This machine produced from the iron bars sixty horseshoes per minute. In 1833 he built a cigar-shaped steamboat 300 feet long, which was afterward lost.

Richard Hoe, who is at the left of Morse (1812–1886), perfected, in 1846, a rotary printing press, which received the name of Hoe's lightning press, and he subsequently invented the Hoe web perfecting press. These inventions are described on another page. Next to him is Erastus Brigham Bigelow, who will be remembered for his inventions in relation to the carpet loom. In 1838 he patented a remarkable loom for weaving knotted counterpanes. In front of him is Jennings, who made important discoveries and inventions regarding the manufacture of matches. Thomas Blanchard (1788–1864), is chiefly known for his eccentric lathe for turning irregular forms, such as lasts, spokes, gunstocks, etc. He also invented a tack machine in 1806, and a steam carriage in 1825; he also built a stern-wheel boat for shallow waters, which is now largely in use in Western rivers. Howe, on the extreme right, is referred to in the article on the sewing machine and also in the brief biographical note which will be found on another page. The group is one of extreme interest as representing those inventors who were especially distinguished about the time of the breaking out of the civil war. It is to be hoped that some artist will come forward and portray the inventors of the last decade of the nineteenth century as faithfully as has the painter of these "Men of Progress."

THE TEXTILE INDUSTRIES OF THE UNITED STATES SINCE 1846.

Modern methods of textile manufacturing had their beginning in the forties, or about fifty years ago. The inventions that have contributed to make the textile industry in the United States what it is to-day first made their appearance at about that time. The modern system of textile manufacturing, therefore, has had an existence of almost exactly half a century. Before then, the various processes of manufacturing were in a sort of transitory or equivocal state of existence—inharmonious one with another. For a hundred years a struggle had been going on for the establishment of an equilibrium between them, which was not fully effected and realized till 1851, when systems, mechanical methods and comparative perfection of product became known to the world at the London international exhibition. The manufacturing world then, for the first time, became cognizant of the fact that there was before it the beginning of a new era of existence. American and foreign inventions had brought about this improved condition of affairs. The great inventions of the eighteenth century had served their purpose and been superseded by those that allowed more continuous and automatic operations. The spinning mule had been made successfully self-acting; the jenny had been thrown aside, while its coadjutor, the billy, was made to serve a new purpose in wool spinning as a more important auxiliary to the carding machine; and the latter for wool had been modified and new devices attached to it for the purpose of simplifying processes and improving the quality of work done. The cotton manufacturing industry had attained development or made more rapid progress to maturity than had been the case with the woolen industry. But at that period both, it may be said, began a new life, regenerated, and started upon their present career. The Crompton fancy cassimere loom, which first appeared in the forties, and John Goulding's inventions affecting carding and spinning, which began to be appreciated at that time, did more to modernize the woolen industry than anything else. The worsted industry, as it is known to-day, had its beginning at that period in the perfection of the combing machine, more, however, as an English than an American industry, the latter appearing later. The silk manufacturing industry, also, began about this time with its centralizing at Paterson, N. J.

At the beginning of the 1850–60 decade, the three textile industries that will be considered in this article, cotton, woolen and silk, were well established, and have remained important factors in the industrial development of the country. Their relative growth may be seen in the following census statistics showing the comparative value of products:

	Cotton.	Per cent.	Woolen.	Per cent.	Silk.	Per cent.
1850	$61,869,184	54·6	$49,636,881	43·8	$1,809,476	1·6
1860	115,681,774	57·0	80,734,606	40·0	6,607,771	3·0
1870	177,489,739	43·6	217,668,826	53·4	12,210,662	3·0
1880	192,090,110	38·4	267,252,913	53·4	41,033,045	8·2
1890	267,981,724	36·7	337,768,524	46·8	87,298,454	12·5

As will be observed, measured by the value of their products, the cotton manufacturing industry was pre-eminent over that of wool in 1850 and 1860, but occupied second place in 1870, 1880 and 1890. Abnormal conditions existed in the sixties, favorable to the woolen and detrimental to the cotton industry, giving the former an impetus that put it first in rank, which it has since retained, though its relative position has been somewhat diminished since 1890, based on the productive capacity of machinery, product values not being obtainable. Since 1890 the productive capacity of the cotton manufacturing industry has increased about 13 per cent, while that of the wool manufacturing industry has increased only about 8 per cent. There is no doubt, however, that the woolen industry still holds its first position in the textile line in the value of products. The silk industry has been steadily gaining, as will be seen, since 1850, till it occupies a relative position of no mean proportions.

The silk manufacturing industry of the United States, in the diversity and excellence of its product, has made commendable progress within the last forty, and even ten or fifteen years. The Chicago Exposition of 1893 revealed an elegance of American silk manufacture that the general public scarcely dreamed of as having an existence. In 1850 the silk manufacturers of this country were confined almost wholly to sewing silk, and no marked progress was made till after 1870, when, by the census of 1880, it was seen that considerable advances had been made in the manufacture of dress goods, which by 1890 became of the first importance with that of ribbons. In color, design and finish, American silk dress goods compare favorably to-day with the best made abroad. The silk industry is chiefly (91 per cent) confined to the four States of New Jersey, New York, Pennsylvania and Connecticut, centralized in certain localities, Paterson, N. J., being first in importance. The status of the silk industry in the United States may be seen from the following statistics, taken from the 1890 census:

VALUE OF PRODUCTS.

United States, gross value				$87,298,454
New Jersey,	Paterson	$22,058,624		
	Elsewhere	8,701,747	$30,760,371	
New York,	New York City	13,579,462		
	Elsewhere	5,838,334	19,417,796	
Pennsylvania,	Philadelphia	8,059,604		
	Elsewhere	11,297,942	19,357,546	
Connecticut			9,788,951	79,324,664
In other States				$7,973,790

The silk industry is centered chiefly about Paterson, New York and Philadelphia. Not far from 60 per cent of it is so situated.

Industries.	Capital.							Value of Products.
	Aggregate.	Value of Plant.				Live Assets.		
		Total.	Land.	Buildings.	Machinery, Tools, and Implements.			
Lumber and other mill products from logs and bolts	$496,339,968	$294,325,888	$156,539,097	$31,273,584	$106,513,257	$202,014,080		$408,667,575
Iron and steel	373,478,018	210,830,316	31,553,087	42,766,656	136,510,573	162,647,702		430,954,348
Cotton goods	354,020,843	230,998,567	23,227,097	69,742,664	138,025,806	123,027,276		267,981,724
Woolen goods	$130,989,940	$57,820,243	$6,534,819	$19,332,575	$31,952,847	$73,169,697		$133,577,977
Worsted goods	68,085,116	27,890,810	2,842,769	7,962,865	17,085,176	41,194,306		79,194,652
Carpets	38,208,842	17,375,384	2,884,139	5,559,456	8,931,787	20,833,458		47,770,193
Felts	4,460,021	1,865,984	276,780	714,453	874,751	2,594,037		4,054,768
Wool hats	4,142,224	1,194,389	144,350	381,105	668,934	2,947,835		5,329,921
Hosiery and knit goods	50,607,738	23,574,761	2,271,466	6,194,088	15,109,207	27,032,977		67,241,013
Total	$296,494,481	$129,721,571	$14,954,328	$40,144,544	$74,622,704	$106,772,910		$337,768,524

The relative status of the cotton and woolen industries, as it existed in 1890, and which is preserved to-day, or nearly so, may be seen in the foregoing table. The four leading manufacturing industries of the United States are here given, the lumber manufacturing interest holding the commanding position in the amount of capital employed, without including planing mill products and the more advanced articles of wood manufacture. Iron and steel rank next, without including anything manufactured therefrom. The manufacture of cotton goods occupies the third, and of woolens, the fourth position. In the value of products the relative positions are somewhat changed. But taking the two great textile industries—cotton and woolen—together, and, in amount of capital and value of products, they stand supreme over all others. Taking all the six New England States together, where these manufactures mainly exist, 34 per cent of the capital invested in all kinds of manufactures is represented in the cotton (21 per cent) and wool (13 per cent) manufacturing industries. The importance of these industries to that section are thus seen, and the effect their prosperity has upon the communities in which they are located.

The cotton manufactures of the United States, as noted above, advanced in the value of their products from $62,000,000 in 1850 to $268,000,000 in 1890, or 332 per cent. In number of spinning spindles the advance was from 3,600,000 to 14,200,000, or about 300 per cent. The increase in value of product and in number of spindles was about the same for this period. The number of spindles in 1846 was about 2,400,000; in 1895 it was 16,100,000, an increase of 570 per cent, and the annual consumption of cotton, per spindle, was 73·4 and 80·5 pounds respectively. The consumption, per spindle, it would thus appear, has increased but slightly within the past fifty years. But important factors have to be considered in this connection; as consumption per spindle is, after all, no more than a statistical curiosity, meaning much or little, according as it is used. Speed of spindle and count of yarn must be taken into calculation. The productive capacity of a spindle to-day is about 44 per cent greater (some are inclined to put it more) than it was fifty years ago, so that measured by this standard the cotton manufacturing industry has advanced within the past fifty years not 570 per cent, but 866 per cent. That this is not shown in the consumption of cotton is due to two causes: less running time and finer counts.

The progress that has been made in the mechanical

processes of cotton manufacturing is gaged more satisfactorily by the advance that has been made in the improvements in spinning on the ring frame. This machine is peculiarly an American invention, while the mule is not. In 1890, 63 per cent of the number of spindles in the United States belonged to this machine. It asserted its value to manufacturers before 1850, but little was done to it or any machine used in cotton manufacturing till after the late war, more than in perfecting details. In this latter respect, however, the progress was marked, so that by 1865 all the mechanical processes had been brought to a high standard of efficiency, equal, if not superior, to anything of like character observed in other branches of the textile industry. Even since the war the perfecting idea has chiefly engaged the time and attention of machine builders, though of late years the introduction of what is known as the revolving flat card (an English invention), and more particularly the Northrop automatic loom, has given cotton manufacturing a new impetus of great significance.

In the spinning frame the productive capacity and progressive steps of a cotton factory are distinctly noted. The machine has not till quite recently been brought to a sufficiently high state of perfection for spinning fine counts of yarn to bring it into competition with the mule, and especially so in the spinning of fine weft. A very recent invention gives great promise of overcoming difficulties of this kind, and within a few months it has been put into practical operation in one of the fine yarn mills of New England upon weft as fine as number 110, which to a manufacturer means a tremendous advance in this method of spinning, and which to him has much greater significance when it is stated that this weft yarn has all the characteristics of mule yarn, with the front or delivery rolls of the machine speeded at 84 turns per minute and the spindles putting in 38·92 twists per inch. This is probably the greatest advanced step taken in cotton manufacturing within the last quarter of a century or more, with the exception of that in weaving by the Northrop loom, which is a wonderful product of American ingenuity and persistent enterprise. This loom ranks with the self-acting mule and the Crompton fancy cassimere loom as the grandest invention in the textile machinery line within the present century. It is epoch making.

The tendency of cotton manufacturing in the New England States is toward finer yarns and goods, more than what is indicated in the consumption of long-stapled cotton of domestic Sea Island and foreign growth. Still, the latter furnishes the only means of estimating it. The consumption of this kind of cotton is nearly 60,000,000 pounds to-day to less than 16,000,000 pounds seven years ago, when fine spinning by Northern mills received a new vitality due to the competition of Southern mills which had become particularly sharp on coarse yarn spinning. To-day, about six per cent of the consumption of Northern mills consists of long-stapled cotton for specially fine yarns, while in 1889 and 1890 this consumption was somewhat less than two per cent. The progress toward the spinning of extra fine yarns is evident, yet it cannot be said that American mills are more than at the beginning of an era of fine yarn spinning.

The wool manufacturing industry of the United States has always been one of particular solicitude for legislators and others. Wool growing and wool manufacturing have for the last thirty years been mutually supporting in a legislative way. Within the last fifty years the wool manufacturing industry has expanded from an annual product of about $30,000,000, in 1850, to nearly $338,000,000, in 1890. In the forties, and for many years thereafter, the woolen product of this country was mainly broadcloths, flannels and satinets, all honest goods to the extent of using pure wool, very little shoddy or wool substitutes being employed till after 1860, when the practice of using adulterants was largely indulged in, with many examples of creditable success so far as skill in deceptive manufacture was concerned. The tendency toward larger factories and concentration of capital is noted in the census of 1860, which gave 1,476 establishments capitalized at an average of $26,300 per establishment, compared with an average of $145,000, as given in the census of 1890. The changes and progress in the woolen industry may be epitomized thus: plain goods of pure wool, as broadcloths, satinets and flannels, with a tendency to fancy cassimeres, from 1845 to 1860; fancy cassimeres and flannels, with a tendency to worsted fabrics for men's and women's wear, from 1860 to 1880; and since 1880, worsted fabrics for men's and women's wear, with no particular tendency away from these fabrics, all energy being devoted toward their perfection and attractiveness. These changes have been brought about by the mechanical inventions which have made these manufactures possible in a manner that appealed to the taste of the fashionable world. The chief mechanical factors in these changes were the loom and the comb, now brought to a remarkably high state of efficiency. There is probably a third more worsted fabrics made now than in 1890. It is the combing machine, for wool and cotton, that is to act the chief part in determining the character of American textile manufactures for the next ten years or more. It is only within the last fifteen years that any conspicuous advance has been made in combing comparatively short-stapled wool like the merino. The introduction of a class of machinery capable of effecting this has revolutionized the wool manufacturing industry of this country. The value of the worsted manufactures of our mills has increased from $3,701,378 in 1860, per annum, to over $100,000,000, in 1895.

The manufacture of knit goods has increased rapidly within the last few years, of which there are no official statistics, in line with the progress made during the decade of 1880-90, within which period there was an advance in the value of products of 131 per cent, exceeding that of any previous decade. Before 1850, the knitting industry was of small concern, not large enough to excite more than local interest.

David Dudley Field. S. F. B. Morse. Daniel Huntington. Cyrus W. Field. Wilson G. Hunt.
Peter Cooper. Chandler White. Marshall O. Roberts. Moses Taylor.

PROJECTORS OF THE TRANSATLANTIC CABLE.

THE SUBMARINE CABLE.

The history of telegraphy gives an early date to the first conception of a submarine cable, as many of the earliest experiments in telegraphic transmission were made under water with an insulated wire. Morse's experiments of 1842 between Governor's Island and the Battery in New York gave him a basis for his prediction that the Atlantic would yet be crossed by a telegraph cable. In 1845, Ezra Cornell, who, we have seen, is identified with the early progress of the telegraph, laid a cable across the Hudson from Fort Lee to the city of New York, which did good service for a year, when it was destroyed by ice. In Europe, the first genuine submarine cable dates back to 1850, when a gutta percha covered copper wire was laid between Dover and Calais, which lived only a single day, friction against the rocks destroying its insulation. Another one was laid in 1851. This new one was armored with ten galvanized iron wires and operated for many years successfully. Two years later Dover and Ostend were connected.

It now became evident that the time was approaching for carrying out Morse's prophecy. Mr. Brett, of England, had been identified with the Dover-Calais cable. Mr. Cyrus W. Field and other capitalists with Mr. Brett organized a company in 1854, and Mr. Field obtained a franchise from the provincial government for fifty years for landing transatlantic cables in Newfoundland. In 1856 soundings were made between Ireland and Newfoundland, and after several attempts a successful cable was laid between Nova Scotia and Newfoundland. The first attempt at spanning the ocean began on the 7th of August, 1857, when the English ship Agamemnon and the American ship Niagara laying a cable started from Valentia, Ireland, and directed their course for St. Johns, Newfoundland. The cable broke on the third day. A second attempt was made in 1858. This time the work of laying the cable was commenced in mid-ocean, the ships separating and proceeding shoreward, one to the east and one to the west, each laying cable as they separated. Two failures in the cable caused the abandonment of this expedition when about three hundred miles, at the most, of cable had been laid. Again the effort was made, and on the 5th of August, 1858, the third attempt ended, the laying was successfully accomplished, and Cyrus W. Field sent his first telegram across the ocean from America to Ireland on the 7th of August of that year. The insulation soon began to fail, and on the 1st of September the cable broke down entirely. Oliver Wendell Holmes' poem on the subject of De Sauty, the electrician of the company, with his message, "All right, De Sauty," as its refrain, will be recalled in connection with this breaking down of the thin strand on which so many hopes depended.

Between August 13 and September 1, 1858, 129 messages of 1,474 words were sent westward, and 271 messages of 2,885 words were sent eastward, when the cable failed. A message from Queen Victoria to the President of the United States, 99 words long, required 67 minutes for its transmission. Endless trouble was experienced in operating the cable before it ceased to work at all, and up to December 1, 1858, the company had expended $1,834,500 in its failure. The interval that elapsed between this and the successful laying of the next cable was due largely to the civil war, but during the twelve years from 1854 to 1866 Mr. Field never abandoned the subject, and crossed the ocean some fifty times, largely in the prosecution of the plan.

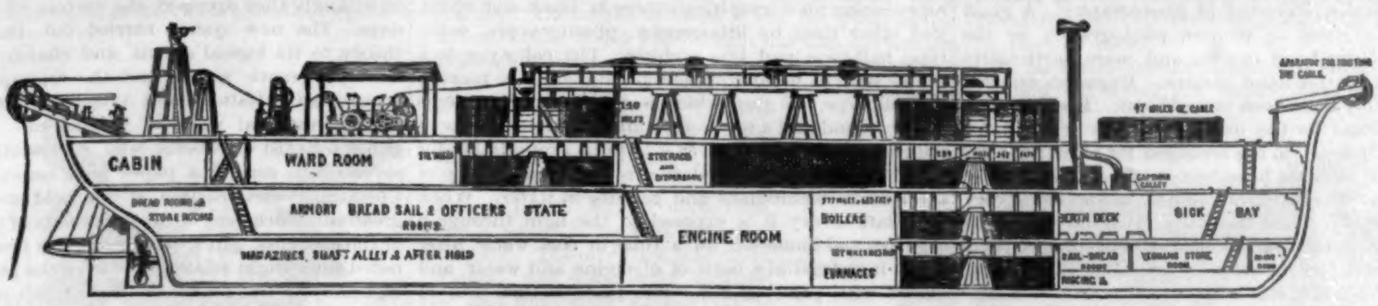
A new company was formed in 1866. A second cable had been laid part way across the ocean and abandoned the year previous, breaking after 1,200 miles were laid. The new company started a new line across the ocean and intended to pick up the abandoned cable and put that to work also. The line was commenced in Ireland, on the 13th of July, 1866, and was finished on the 27th of the same month, and on the 4th of August, 1866, the Atlantic cable was declared open to the public.

The other cable was grappled for and recovered, and it was completed, thus giving two lines between the continents. Cyrus W. Field received great renown from his work. The United States Congress voted him a gold medal, the Paris Exposition of 1867 gave him a gold medal, and he would have received high honors in England, it is said, had he not been a citizen of another country.

The Great Eastern, the most monumental failure in the history of steam navigation, seemed for a time to have found a scope for her abilities in the laying of transatlantic cables, but since her time many special cable ships have been built, with every appliance for successful and cheap prosecution of the work of laying cables, and the Great Eastern has been broken up for old iron. The cable is payed out over the stern of the ship through special apparatus by which any desired strain can be put upon it. The theory is that it has to be laid upon the bottom, no suspension from summit to summit of subaqueous ridges being permissible. Hence it has to be fed out at varying strain and rate according to the slope of the bottom on which it is being deposited. The work has become wonderfully systematized. Cables are laid at sea with the same unconcern that attends any ordinary voyage in a well equipped ship under favorable conditions. The system of buoying the ends of cables has become so perfected that a ship now has no hesitation in dropping the end of the cable, to be picked up at any time convenient in the future. Nevertheless, the early struggles in the laying of the cables form most impressive lessons in the ability of mankind to overcome obstacles.

After the failure of the first European-American cable, a new route was agitated from Labrador to Scotland, by way of Greenland, Iceland and the Faroe Islands. This route is about 1,800 miles long, and the

gest water distance is 600 miles. Other deep sea cables between Sardinia, Malta, and Corfu, and one in the mouth of the Red Sea to India were laid shortly after and they failed. A committee of the most eminent electricians was organized by the English Chamber of Commerce and the Transatlantic Company to study the subject, and after eighteen months of labor they issued an elaborate report in 1863. Without waiting for their report a cable between Malta and Alexandria had been successfully laid, in 1861, and in the year succeeding their report, the Persian Gulf cable, about



SECTION OF THE STEAMSHIP NIAGARA ARRANGED FOR LAYING THE TRANSATLANTIC CABLE OF 1858.

1,330 miles long, was successfully laid. This was the major part of the work done prior to the laying of the Atlantic cable in 1866. Sir Wm. Thomson (Lord Kelvin) was identified from its earliest days with the cable laying art, and in his works may be found many graphic accounts of difficulties encountered and how they were surmounted. His instruments were used in the earliest days for the transmission of signals. It was found that with a line of such high capacity, worked with ordinary apparatus, endless difficulties were experienced, but Sir Wm. Thomson overcame them at an early period. His reflecting galvanometer was made to give visual signals by movement of its spot of light upon the scale, and when it was desired to have permanent signals, the siphon recorder traced, by means of ink from a capillary orifice, a zigzag line upon a strip of paper and solved the problem, the great scientist recurring to Morse's original written code produced by his old pendulum apparatus.

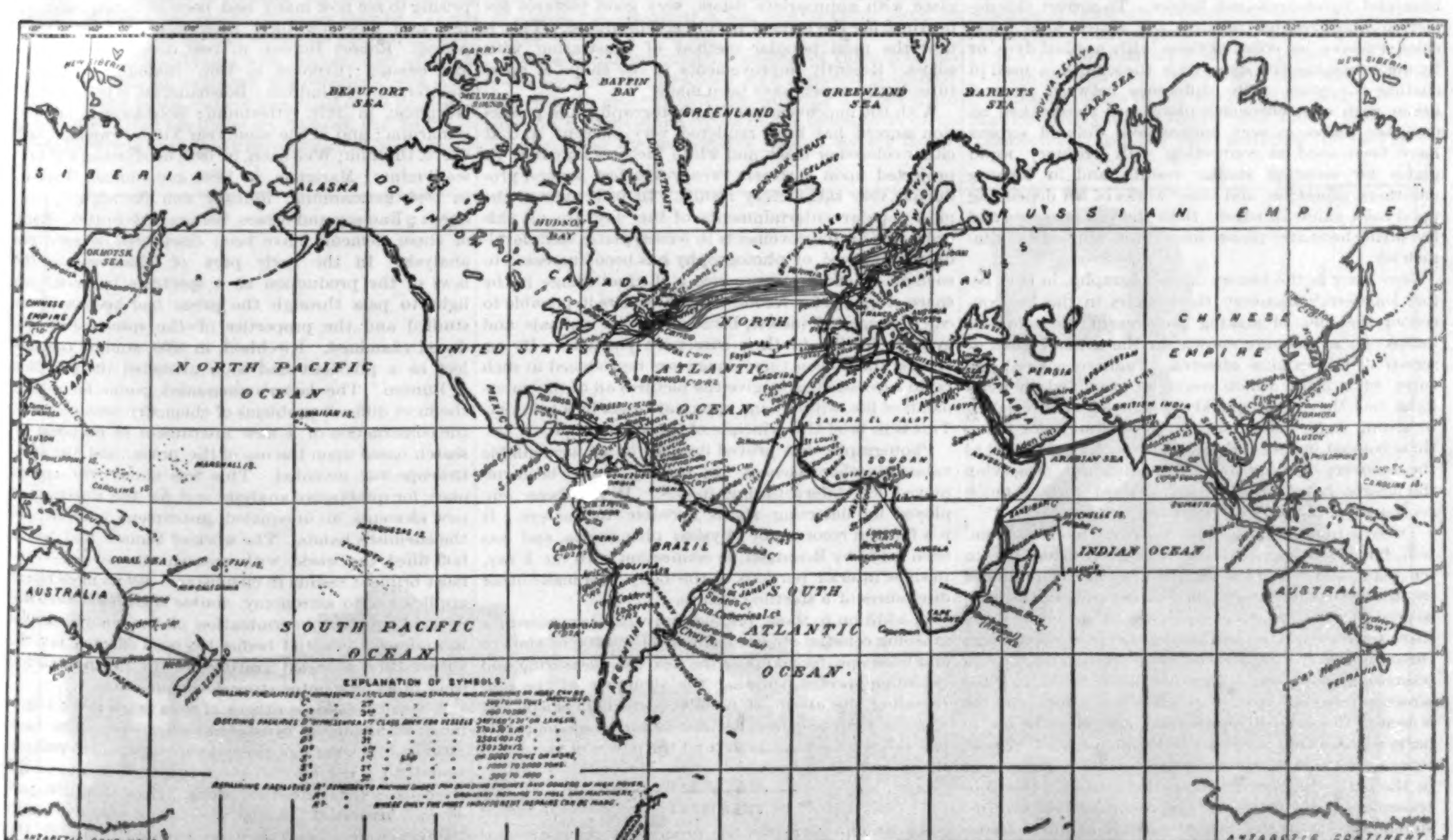
Fleeming Jenkin, the Edinburgh professor (whose life has been so charmingly written by Robert Louis Stevenson, a part of whose interest consists in the reflection of the author's own character, as he was registered as a student under Prof. Jenkin at the University of Edinburgh) gives an excellent account of the difficulties experienced by the early cable layers, in which expeditions Jenkin, great sufferer from seasickness as he was, appeared as an enthusiastic worker. To-day all is changed. There are a whole fleet of cable ships used for cable laying and for repairs, and appliances and methods have become systematized to the last degree. Cables are turned out from the factories in lengths of thousands of miles without imperfection, and the world is almost girdled by electric wire, the great Pacific forming practically the only break in its complete circuit, a break soon to be closed.

We have reproduced for our readers, with the kind assistance of the Postal Telegraph Company, the map of the world on Mercator's projection, on which are drawn the many lines of cable now existing. This map is thoroughly up to date, and shows in a most interesting way the amount of work accomplished. One of the most impressive features is the number of lines across the Atlantic Ocean between Europe and America. Hardly less impressive are the remote lines to New Zealand, Australia, Madagascar, and the Mauritius, while in the opposite sense the great Pacific, as yet uncrossed, marks the present limit of man's achievements. There is at present, however, a plan under way for laying a line across the Pacific from Vancouver to Japan, and the full plans were recently placed before Congress, but up to the present writing the necessary co-operation has not been obtained.

In the electrical outfit of the cable system, the principal progress has been in the adoption of a more delicate type of instruments for the transmission and reception of messages. The cables are generally worked on the condenser system, there being no through metallic circuit. The Thomson and Varley transmission apparatus increased the old speed eight fold. Thomson's siphon recorder quadrupled the speed of the systems used before its advent.

The cuts accompanying this article are of special value. The section of the Niagara is reproduced from a contemporaneous wood cut which appeared in the SCIENTIFIC AMERICAN in 1858. The portrait group is a reproduction of a painting now preserved in the New York Chamber of Commerce, and represents the incorporators of the Atlantic cable of 1858 assembled in the library of Cyrus W. Field, the philanthropist-inventor Peter Cooper presiding. In the background the artist, the great American portrait painter, Daniel Huntington, has introduced his own portrait. The cost of the painting alone was $20,000, and a long list of donors subscribed for its production.

Finally, the map gives the authoritative presentation of the world's network of cables corrected up to date specially for the SCIENTIFIC AMERICAN.



SUBMARINE CABLES OF THE WORLD, WITH THE PRINCIPAL CONNECTING LAND LINES, ALSO COALING, DOCKING AND REPAIRING STATIONS.

FIFTY YEARS OF PHOTOGRAPHY.

In the entire range of invention and discovery nothing shows a more brilliant series of successes than the art of photography.

A hundred and fifty years ago, copies of writing had been made by the action of light on sensitive paper. Giambattista Porta had invented the camera obscura; and more recently Niepce and Daguerre by different methods had succeeded in making sun pictures; and Fox Talbot had invented the calotype or talbotype; Herschel had given to the impression made from the object the name "negative" and to the print from the negative the name "positive."

Fifty years ago, in 1846, Schonbein discovered gun cotton, and soon after collodion was produced by making a solution of gun cotton in alcohol and ether. It was almost immediately adopted by Archer for a film in lieu of albumen and gelatine. Pictures produced on the sensitive film having collodion as the basis superseded the calotype and daguerreotype, and were made almost exclusively after this discovery up to within fifteen or sixteen years. This film is still used by many photographers for special purposes, but more particularly in photo-engraving, and for transparencies and lantern slides. The collodion film was used for making negatives as well as positives; some of the best photographic pictures ever produced were made by means of wet plate collodion film negatives, albumenized paper being used in making the positive prints. Prior to the use of albumenized paper sensitized with the silver salts, glass positives, called ambrotypes, were introduced by making a very thin negative image and backing the plate with asphaltum varnish or black velvet, the black background producing a positive effect. In some cases they were bleached by means of a solution of mercuric chloride. Collodion positives are still made upon thin japanned iron, commonly called tintypes.

After a great many experiments the modern dry plate was produced, not in its present state of perfection, but in a way which indicated its capabilities. The gelatine dry plate could not be made in perfection until after the gelatine itself had been improved so as to render it suitable for this purpose. It is to the perfection of the extremely sensitive dry plate that the great popularity of photography is to be attributed.

Barring the bicycle, probably no craze was ever so widespread as that of modern photography. Methods of manipulation and improvements in lenses and apparatus have kept pace with improvements in the art itself, and the large demand for apparatus and material effected a corresponding reduction in prices. Lenses have been devised for every use, and the very recent improvements in optical glass have rendered it possible to produce lenses which are marvels of perfection.

It is needless to mention the improvements in cameras and portable apparatus, for we think it would be almost a rarity to find a family of which some member is not practically interested in photography. A great impetus was given to modern photography by the invention of the hand camera and more particularly that of the magazine hand camera. Magazine cameras in great variety have been brought out. Most of them have been fitted for the use of roll films or cut films, but a small proportion are arranged for receiving glass plates. Such cameras have been made as large as 8 by 10. The beautiful modern folding camera, being very light and portable, has become a great favorite with both professionals and amateurs. It is even more portable than the magazine camera.

From the ordinary side window as a source of illumination, the daguerreotypist turned to the skylight, and special skylights, some of them of large size, were constructed and used to great advantage in the production of pictures which have never been surpassed in soft, delicate shading.

After the invention of highly sensitive plates it was possible to make a good picture with a smaller skylight, also with a good sidelight, when suitable screens were provided. With sensitive plates came the use of artificial lighting and flash lights for instantaneous work in the night, and in caves and dark places.

Since the development of the electric light many photographic establishments have been fitted out with electric lighting apparatus, permitting of taking portraits at night and in cloudy weather. An additional advantage in the use of artificial light is that of carrying on the work on the first floor, thus saving stair climbing or traveling in the elevator. With proper management the amateur photographer may procure flashlight pictures at home in the evening which compare favorably with daylight work.

Early in the history of photography it was noticed that true color values were not rendered in any photographic pictures. Yellow, red, and green always appeared darker in the picture than in the object, while blue and violet appeared lighter. To correct this defect in photographic pictures the plates were made color sensitive by coloring them with applied dyes, or by incorporating the dyes with the emulsion used in coating the plate. The difference between pictures taken with orthochromatic plates and those taken on ordinary plates is very noticeable. Colored screens have been used in connection with ordinary rapid plates for securing similar results, and in copying paintings, tapestries, and other works of art depending upon color value for effect. Both the yellow screen and the orthochromatic plates have been applied simultaneously.

Very early in the history of photography, in fact before Daguerre's discovery, the workers in this line conceived the idea of making pictures in the colors of nature, or as they are shown on the ground glass or screen of the camera obscura. Fugitive colored pictures were made which could be examined by weak light, but they were quickly destroyed when exposed to strong light. No means was ever found for fixing these colored images. Experiments looking forward to the discovery of some means of fixing and preserving the images have been carried forward without much success since the days of Daguerre.

Tricolor photography is not a strictly modern invention, but it has been perfected to a great extent within ten years, and very pleasing pictures can be produced by this process, although they do not present the ideal colored picture. Such pictures are produced by using three separate plates and taking the pictures through three separate color screens, red, green, and blue; a positive made from a negative taken through a red screen is transparent through all places where pure red is seen in the subject represented, also more or less in parts representing purple or violet and orange. A positive taken through the green screen will be transparent in the parts that are green in the subject. It will be transparent also in the parts representing yellow. In a similar way a picture taken through a blue screen is transparent to the parts representing the blue portions of the subject.

According to one method, the prints from the negative are made upon sensitized gelatine, the gelatine carrying the color which is required to build up the portion of the picture demanding that color. When these three prints are made and superposed, they reproduce approximately the colors of the scenes represented.

A modification of this method which results in truer colors is accomplished by making three positive black and white prints representing the three colors and projecting them on a screen, where they are superposed, suitable colored screens being placed in front of each positive. Some very beautiful effects are produced by this method.

Lippman, of Paris, not long since discovered a very simple and interesting method of producing photographs in color. He first produces a suitable negative, prints a positive from the negative and backs up the positive with a film of mercury. The image is seen by reflected light, and the colors are produced by interference of light in a manner similar to Newton's rings.

Among other developments in photography within very recent years may be mentioned several methods of reproducing photographic pictures in black and white, and other tints by lithography, photogravure, collotype, half-tone and line etching. The collotype is a simple style of photographic reproduction. In making the collotype, the glass which is to support the film is finely ground and a solution of albumen and silicate of soda and water poured over it to form a foundation for the film. Upon this foundation is poured a solution of ammonium bichromate and gelatine in water. When the plate is dry it is exposed to the light through a negative and immersed for a time in cool water, after which it is dried in a bath of glycerine and water, and coated with printing ink. The plate is then printed according to the method of the lithographic printer.

In photogravure the shadows are depressed in the plate, and the printing is done on practically the same principle as that of steel or copper plate printing.

In making a photogravure, a transparency or positive is taken from a negative by any of the well-known methods, and a copper plate larger than the print to be made is cleaned and dried and then coated with a solution of gelatine and potassium bichromate in water. The plate is then dried, placed in a printing frame, and exposed through the transparency or positive, after which the surface of the film is dusted, etched and cleaned, when the plate is printed from, after inking and wiping off, either in the same manner as a copper or steel plate engraving, or as an etching, leaving a thin film of color in different positions on the high lights to modify the effects.

In the half-tone process the sensitive plate is exposed in the camera through a grating, which leaves a texture on the negative, which, when printed through on the bichromatized metallic plate, produces lines or dots, which are etched, and which, in printing, leave high lights and carry the ink, which produces the shadows. When three plates are made through three colored screens and three impressions are produced from the plate with appropriate colors, very good pictures approximating the tints of nature are produced. This is now the most popular method of illustrating with colors. Recently improvements in the shape of apertures in the screen have been made.

With the improvements in photography, the projection lantern has been rendered very efficient, so that either colored or black and white pictures may now be projected upon a screen twenty-five feet square, producing very satisfactory results. In fact, some of the most popular entertainments of the day are on this order. With improvements in lenses, plates, and developers the speed of photography has been increased to such an extent as to produce a distinct image in the space of $\frac{1}{5000}$ of a second. This renders it possible to catch images of insects, birds and other animals and even projectiles in their successive positions. By reversing the process these images are reproduced in such rapid succession as to give the pictures all of the movements of life, without any apparent break in continuity. This is in brief the principle of the kinetoscope.

Photography has proved itself to be of incalculable value to other sciences. In surgery it has been employed for differentiating tissues. It has been employed for detecting stains invisible to the eye. It is a faithful recorder of physical phenomena, and has been made by Roentgen, in connection with the X ray, to show interior portions of the body, and make other disclosures of a startling nature.

In addition to these, photography has been used for grasping celestial objects beyond the power of the eye and telescope, for mapping the heavens, measuring and recording spectra, showing the structure of the sun, revealing the extent of nebulæ, picturing comets, and making records of eclipses and other phenomena. It has also revealed things beyond the power of vision and the microscope.

CHEMISTRY.

An attempt to review the progress of chemistry during the last fifty years requires more space than this entire issue would put at our disposal. Fifty years ago chemistry and physics were both established on a firm basis. Chemistry had had nearly three-quarters of a century in which to develop its theory and had become formulated into an exact science in which the results were attested by the balance and in which exact analyses were applied by some of the most brilliant minds that the world has ever seen. At that time and for many years subsequent the old binary or dual system of Berzelius was still employed by chemists, and those who graduated from the polytechnic schools and colleges up to 1870 studied chemistry under what is known as the old system. Dumas opposed the Berzelius system, and, supported by those constituting the French school of chemists, obtained a victory about 1832. Nevertheless, for forty years after that period the old system held sway, though of course to a greatly diminished extent. To-day some of the old time chemists who have been unable or indisposed to drop the old system and have not changed it for the new still write sulphuric acid HO,SO_3 instead of H_2SO_4, and so for other compounds. Those who, like the writer, studied chemistry under the old system and had to change it for the new realize how much is involved in it; how great an improvement the new is over the old, and yet how unwillingly they dropped the system of their student days. The new system carried out Dalton's atomic theory to its logical extent, and chemistry took on a more systematic aspect, and the consequences of the acceptance of Dalton's and Avogadro's law appeared in the monumental work of Mendeleeff. The indefatigable scientist of Siberia, who, it is worth noting, is a seventeenth son, in a paper read before the Russian Chemical Society in 1889, at one bold stroke made his great announcement of the periodicity of the properties of the elements. In a halting way his predecessors had noted some slight relations between the atomic weights, especially of the four haloids, but Mendeleeff applied his system to the entire scheme of elements, drew up his famous table, showed how in accordance with it the elements ought to occur, and at once established one of the greatest triumphs of science, one that led to some of its most remarkable achievements. This table was filled with blank spaces where, in order to carry out the complete series, elements ought to exist. Almost immediately some of the spaces began to be filled by newly discovered elements, so that it was recognized that Mendeleeff's law was, to a certain extent, prophetic and might point out the existence of elements yet unknown to us. It also led to a more accurate censorship of the atomic weights and of their other properties. Thus uranium, whose atomic weight was formerly taken as 120 and then 180, required for the Mendeleeff law 240, a value confirmed by independent experiments of other chemists. Uranium is the element which marks one end of the Mendeleeff scale. Gold, tellurium, and titanium refused to come into the law under their old atomic valuations, but new determinations of atomic weights have brought them into the law with the others.

A good indication of the work of chemistry is in the discovery of new elements. Upon looking at the dates of the discovery of the different elements it is most surprising to see how many had been discovered prior to 1846 and how few have been discovered since that period. Robert Bunsen in 1860 discovered rubidium and cæsium; Crookes, in 1862, thallium; Reich and Richter, in 1863, indium; Boisbaudran, in 1875, gallium; Marignac, in 1878, ytterbium; Boisbaudran, in 1879, samarium; and in the same year Nilson, scandium, and Cleve, thulium; Welsbach, in 1885, neodymium and praseodymium; Marignac, in 1886, gadolinium; Winkler, in 1886, germanium; Ramsay and Rayleigh, in 1894, argon; Ramsay and others, helium, 1888 to 1895. Many of these elements have been discovered by spectrum analysis. In the early part of this century the laws of the production of a spectrum by permitting light to pass through the prism had been seriously studied and the properties of the spectrum so produced examined. Kirchhoff, in 1859, studied the subject as a physicist and soon attracted the attention of Bunsen. The latter's unequaled genius for solving the most difficult problems of chemistry brought about the construction of a new instrument of chemical research based upon the use of the prism, and the spectroscope was invented. This was about 1860, and at once, for qualitative analysis and for the discovery of new elements, an unequaled instrument was put into the chemist's hands. The work of Bunsen and Kirchhoff filled the world with amazement and led to the most brilliant results in chemistry. By its more recent application to astronomy, double stars have been discovered and the determination of the composition of incandescent celestial bodies has been effected, and the substitution of ruled gratings for the prism has led to some of its most interesting developments.

Woehler's classic synthesis of urea marked the beginning of advanced synthetical chemistry. The mere catalogue of what has been done in organic synthesis would fill a volume. Coal tar has proved one of the great bases for synthetical work. Perkin, in 1858, patented a dye stuff, aniline violet, and that dye marks the beginning of an enormous chemical industry, the production of coal tar colors. Color after color was discovered, and the very existence of the great madder fields of Europe was threatened by the discovery of coal tar alizarine. In analytical chemistry constant improvement was effected. Bunsen brought gas analysis to a wonderful degree of perfection. His methods, unequaled for accuracy and precision, were gradually supplanted in the technical world by simpler ones. The chemists' balance was improved largely by the labors of Becker and other world-famous manufacturers. The first edition of Fresenius' works on analytical chemistry goes back fifty years; the great master of two generations of chemists in his role of master of the world of analytical chemists being almost contempora-

ous with the beginnings of the SCIENTIFIC ERICAN.

New methods of attack have been applied. The elec- furnace, in the hands of M. Moissan, has yielded markable results. Fluorine, the element which for many decades resisted isolation, was isolated by him. the utilization of electricity, rare metallic elements re also reduced from their compounds, and the elec- current was applied by Classen with much success to the problems of analysis by electrolysis of aqueous lutions of the double oxalates. The synthesis of car- n and hydrogen has been effected on the large scale by the electric furnace, in which carbides decomposable by water are first produced. The decomposition of these by water gives acetylene gas, a veritable triumph of synthesis.

THE FIRST PHONOGRAPH.

The every-day appliances of the laboratory have been improved beyond the dreams of old time chemists. Now special apparatus is procurable for all purposes. Rapid filtration, introduced originally by Bunsen, is really one of the notable improvements of the period we treat of, and in the hands of Gooch and others has been greatly developed and improved.

It may seem that the chemist's work is done, but it is not. The discovery of metallic carbonyls is an illustration of how great recent discovery may be. It was found by Mond that carbon monoxide gas had the wonderful power of combining with nickel, and also less freely with iron at ordinary temperatures, and could carry them off in the state of gas. This dates back only a few years. Had the discovery yielded the fruits expected, it would have fairly revolutionized some industries. The same is to be said for calcium carbide and acetylene gas, already alluded to.

THE PHONOGRAPH.

In December, 1877, a young man came into the office of the SCIENTIFIC AMERICAN, and placed before the editors a small, simple machine about which very few preliminary remarks were offered. The visitor without any ceremony whatever turned the crank, and to the astonishment of all present the machine said: "Good morning. How do you do? How do you like the phonograph?" The machine thus spoke for itself, and made known the fact that it was the phonograph, an instrument about which much was said and written, although little was known.

The young man was Edison, and the phonograph was his latest invention. The editors and employes of the SCIENTIFIC AMERICAN formed the first public audience to which it addressed itself. Edison, even then, was a well known and successful inventor. The invention was novel, original, and apparently destined to find immediate application to hundreds of uses. Every one wanted to hear the wonderful talking machine, and at once a modified form of the original phonograph was brought out and shown everywhere, amusing thousands upon thousands; but it did not by any means fulfill the requirements of the inventor. It was scarcely more than a scientific curiosity or an amusing toy. Edison, however, recognized the fact that it contained the elements of a successful talking machine, and thoroughly believed it was destined to become far more useful than curious or amusing. He contended that it would be a faithful stenographer, reproducing not only the words of the speaker, but the quality and inflections of his voice; and that letters, instead of being written, would be talked. He believed that the words of great statesmen and divines would be handed down to future generations; that the voices of the world's prima donnas would be stored and preserved, so that, long after they had passed away, their songs could be heard. These and many other things were expected of the phonograph. It was, however, doomed to a period of silence. It remained a toy and nothing more for years.

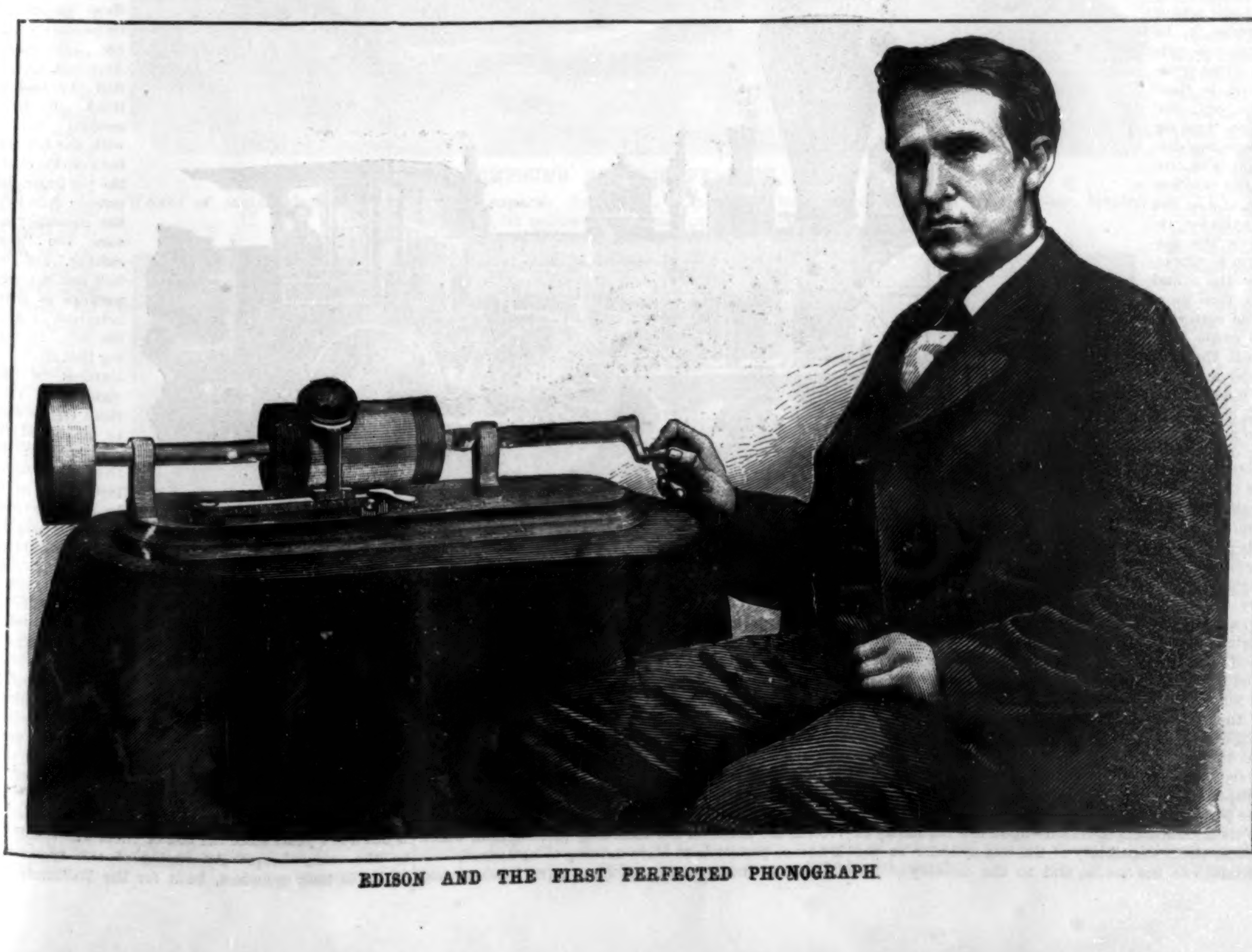
The original instrument consists of three principal parts—the mouthpiece, into which speech is uttered; the spirally grooved cylinder, carrying a sheet of tinfoil which receives the record of the movements of the diaphragm in the mouthpiece; and a second mouthpiece, by which the speech recorded on the cylinder is reproduced. In this instrument the shaft of the cylinder is provided with a thread of the same pitch as the spiral on the surface of the cylinder, so that the needle of the receiving mouthpiece is enabled to traverse the surface of the tinfoil opposite the groove of the cylinder. By careful adjustment this instrument was made to reproduce familiar words and sentences, so that they would be recognized and understood by the listener; but, in general, in the early phonographs, it was necessary that the listener should hear the sounds uttered into the receiving mouthpiece of the phonograph to positively understand the words uttered by the instrument.

In later instruments exhibited throughout the country and the world, the same difficulty obtained, and perfection of articulation was sacrificed to volume of sound. This was necessary, as the instruments were exhibited before large audiences, where, it goes without saying, the instrument, to be entertaining, had to be heard. These instruments had each one mouthpiece and one diaphragm, which answered the double purpose of receiving the sound and of giving it out again.

IMPROVED RECORDING AND REPRODUCING PHONOGRAPH OF 1896.

Finally it was made known to the public that the ideal phonograph had been constructed; that it was unmistakably a good talker; and that the machine, which most people believed to have reached its growth, had after all been refined and improved until it was capable of faithfully reproducing every word, syllable, vowel, consonant, aspirate and sounds of every kind.

During the dormancy of the phonograph, its inventor secured both world-wide fame and a colossal fortune by means of his electric light and other well known inventions. He devoted much time to the phonograph, and not only perfected the instrument



EDISON AND THE FIRST PERFECTED PHONOGRAPH.

itself, but established a large factory provided with special tools for its manufacture, in which phonographs are turned out in great numbers.

The improvements reduced the instrument to about the size of an ordinary sewing machine. In its construction it is something like a very small engine lathe; the main spindle is threaded between its bearings and is prolonged at one end and provided with a drum for receiving the wax cylinder, upon which the sound record is made. Behind the spindle and the drum is a rod upon which is arranged a slide, having at one end an arm adapted to engage the screw of the spindle, and at the opposite end an arm carrying a head provided with two glass diaphragms which may be interchanged when desirable. One of these diaphragms is used when it is desired to talk to the phonograph, and when the speech is to be reproduced the other diaphragm takes its place. The cutter by which the impressions are made in the wax is attached to the center of the diaphragm and pivotally connected to a gravity arm attached to the side of the diaphragm cell. The reproducing cell contains a delicate glass diaphragm, to the center of which is secured a stud connected with a small curved steel wire, one end of which is attached to the diaphragm cell. The recording and reproducing points are formed of chalcedony.

The spindle of the phonograph is rotated regularly by an electric motor in the base of the machine, which is driven by a current from one or two cells of battery. The motor is provided with a sensitive governor which causes it to maintain a very uniform speed. The arm which carries the diaphragms is provided with a turning tool for smoothing the wax cylinder preparatory to receiving the sound record.

The first operation in the use of the machine is to bring the turning tool into action and cause it to traverse the cylinder. The turning tool is then thrown out, the carriage bearing the recording diaphragm is returned to the position of use, and as the wax cylinder revolves the diaphragm is vibrated by the sound waves, thus moving the cutter so as to cause it to cut into the wax cylinder and produce indentations which correspond to the movements of the diaphragm. After the record is made, the carriage is again returned to the point of starting, the receiving diaphragm is replaced by the reproducing diaphragm, and the carriage is again moved forward by the screw as the cylinder revolves, causing the point carried by the reproducing diaphragm to traverse the path made by the recording cutter. As the point follows the indentations of the wax cylinder the reproducing diaphragm is made to vibrate in a manner similar to that of the receiving diaphragm, thereby faithfully reproducing the sounds uttered into the receiving mouthpiece.

The perfect performance of the phonograph depends upon its mechanical perfection—upon the regularity of its speed, the susceptibility of the wax cylinder to the impressions of the needle, and to the delicacy of the speaking diaphragm. No attempt is made in this instrument to secure loud speaking—distinct articulation and perfect intonation having been the principal ends sought.

The phonograph may be now used for taking dictation of any kind, for the reproduction of vocal music, for teaching languages, for correspondence, and for various other purposes too numerous to mention.

The wax cylinder upon which the record is made is provided with a rigid backing. It is very light and a mailing case is provided for safely mailing it. The recipient of the cylinder places it on his own phonograph and listens to the phonogram—in which he not only gets the sense of the words of the sender, but recognizes his expression, which will, of course, have much to do with the interpretation of the true meaning of the sender of the phonogram.

A very interesting and popular use of the phonograph is the distribution of the songs of great singers, sermons and speeches, recitations, the words of great men and women, music of many parts, the voices of animals etc., so that the owner of a phonograph may enjoy these things with little expense.

Passing over the application of the phonograph to dolls, we will refer briefly to the latest developments of the instrument. It has recently been determined to furnish a perfect phonograph for a moderate price which will reproduce any record with great fidelity. Purchasers will be able to provide themselves with records of any desired character, so that the most interesting of entertainments may be had at a moment's notice. This phonograph is driven by a spring motor in a manner similar to a music box. It is light, compact, and readily operated. Although it is designed for reproducing only, it may for a small additional cost be made to record or to both record and reproduce. The records are made on the recording phonograph, which is now so perfect as to leave nothing to be desired.

Other instruments of this class have been devised within a few years—the graphophone, which is similar to the phonograph, operating on practically the same principle, and the gramophone, which has a flat disk instead of a cylinder and makes a record which is a sinuous groove, by means of a laterally vibrating needle. It reproduces sound by the lateral vibrations caused by the following of the reproducing needle in the groove of the record.

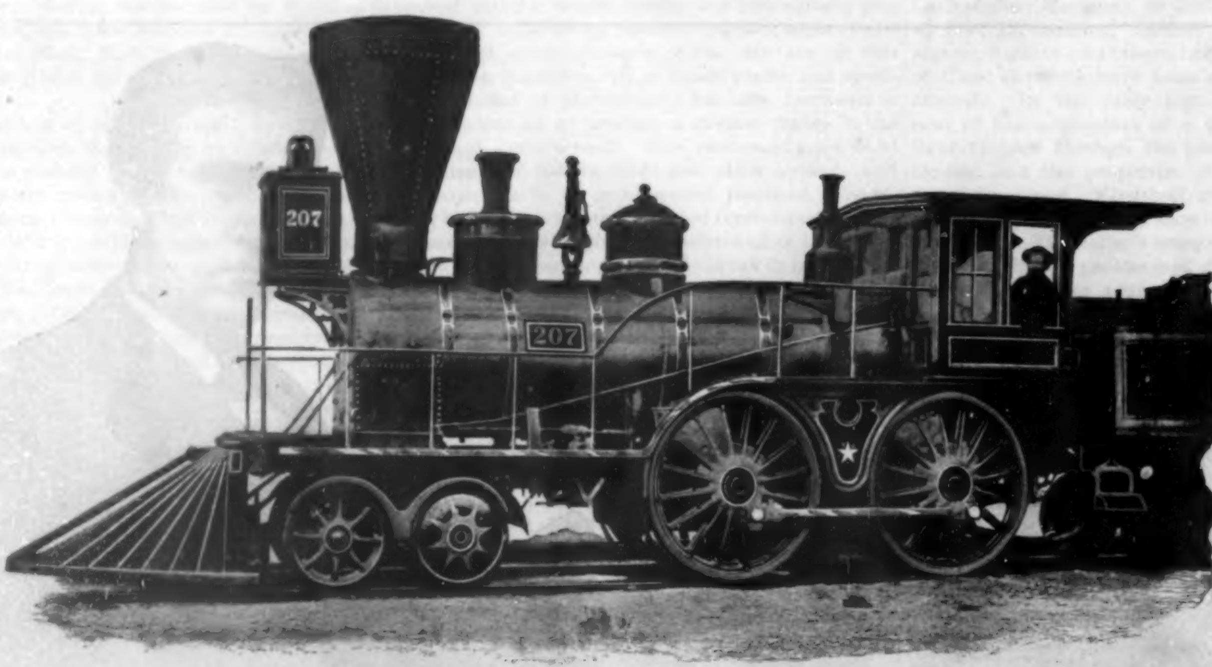
THE AMERICAN LOCOMOTIVE.

The first practical locomotive to turn its wheels upon a track in America was the Stourbridge Lion, an imported English engine. This notable event took place August 9, 1829. The first engineer to run a locomotive in America was Horatio Allen, who handled the throttle on this occasion. It is claimed that the first American-built locomotive to be put into active service was the Best Friend, which was constructed by Mr. E. L. Miller, for the South Carolina Railroad Company. This occurred in November, 1830.

CAMEL-BACK LOCOMOTIVE BUILT FOR THE B. & O. RAILROAD IN 1853.

Cylinders, 19 by 22 inches; drivers, 50 inches; weight, 71,000 pounds; steam pressure, 120 pounds.

In the earliest days of American locomotive building the influence of the original English models is traceable in the designs; but it was not long before the American mechanic began to strike out for himself, and build a machine specially adapted to local conditions. Various original and radical features were introduced, and with such rapidity, that in the brief interval of sixteen years between the trial trip of the Best Friend and the year 1846, which marks the opening of the half century with which we are dealing, the most important elements of the typical American eight-wheel engine, as we know it to-day, may be said to have been substantially established.



INSIDE-CONNECTED EIGHT-WHEELED LOCOMOTIVE BUILT FOR THE B. & O. RAILROAD IN 1854.

Cylinders, 15 by 22 inches; drivers, 60 inches; boiler, 44 inches diameter; weight, 56,000 pounds.

A comparative study of the cuts of early engines of this period will enable the reader to identify, in one design or another, those characteristic features which are distinctively American. He will find the leading truck, the four-coupled drivers, with the fire box between the axles, the bar frame, the outside cylinders, the equalizing levers, the "cow catcher," and the bell, and last, and perhaps as characteristic as any, the cab. In saying that the main features of the eight-wheel American engine were to be found represented in the locomotives of 1846, it is not to be understood that this was by any means, at that time, the accepted type, although it was destined shortly to become so. That was an age of investigation, and the student of American locomotive history is impressed with the number and variety of experimental engines which figured in the twenty years from 1841 to 1860. In the first place, the inside cylinders and the single driving wheel, which have been so very largely retained in English practice, were tried and found wanting for the requirements of those days. The celebrated Globe eight-wheeled inside connected engines were for many years a familiar feature on many New England roads, and it is but a few years since the last of them was consigned to the scrap heap. An engine of this type, with 15 by 22 inch cylinders, built for the Baltimore and

o Railroad in 1854, is shown in the accompanying ...tration. These, however, were notable exceptions ...he general practice, which, early in the period ...er consideration, forsook the easy running of the ...le connected for the greater ...diness of the outside connected ...e.

...we would seek for the cause of the marked difference in the American and English locomotive, starting as they did from a common origin (there were between 25 and 30 engines in all imported from England), it will be found in the different conditions under which the two types had to do their work.

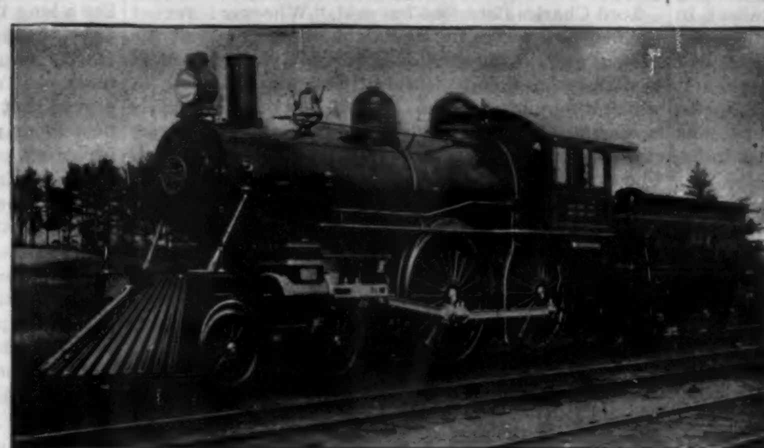
For reasons which are given elsewhere in this issue, the early English roads were built more solidly, and with lighter grades and easier curves than the early American roads. The relatively smooth and straight English track permitted the use of the more rigid plate frame engine with rigid wheel base, and it has continued to be the prevailing type. The cheaper and lighter American track, which was necessitated by the long stretches of thinly peopled country which had to be covered, called for a special make of locomotive, with lateral and vertical flexibility. The lateral adjustment was obtained by means of the leading truck, and the vertical adjustment by the equalizing levers. By these devices, the weight is carried upon three points of support, one forward beneath the cylinders, and one on each side of the fire box. The principle of leverage is so ingeniously applied, that the shock of any one wheel passing an obstruction is distributed and reduced before it reaches the main body of the engine. The combination of these two devices enabled high speeds to be maintained over track which would have ditched an English engine before it had run a mile.

The average dimensions of an 184 engine were as follows: Cylinders, 15 or 16 by 20 and 22 inches; weight, 18 to 20 tons; drivers, 4½ to 5 feet diameter; and the steam pressure varied from 90 pounds to 120 pounds per square inch. In 1848 we find the Baldwin Locomotive Works undertaking to build an express engine to run sixty miles an hour, for which feat they provided her with 17¼ by 20 inch inside cylinders and a pair of 6½ feet drivers; and a little later they built a somewhat similar engine with 15 by 20 inch cylinders and a pair of 6 foot drivers. The single driver was fully tested, with the almost invariable complaint, after trial, that there was "insufficient adhesion." At this time wheels as large as 8 feet diameter were to be seen in service—a size which has never since been reached, although 7 foot drivers are becoming common in up-to-date practice. The ten-wheel engine, with six-coupled drivers, was patented by Septimus Norris in 1846, and the Rogers Locomotive Company turned out their first celebrated ten-wheelers in 1848.

The Stephenson link motion was first employed by Mr. William T. James, of New York, in 1832. It was first adopted as standard practice in American shops by Mr. Thomas Rogers, of the above works, in 1849, and with its reintroduction the evolution of the American locomotive, as to its essential features, may be said to have been complete. The subsequent development has consisted in the perfecting of details, and the variations from the type have been such as were called for by the particular class of service which had to be performed.

In addition to the points of divergence in practice between American and English builders already noticed, it may be said in general that the American locomotive h... always been harder worked than th... English, and that while it has nev... shown such economy in fuel consump... tion, it has always been able to get away with a bigger load. Where the English superintendent would run a train in two sections, each of which would constitute a load well within the hauling capacity of the engine, in America one locomotive would take the whole train, and would be pushed to its utmost capacity in the effort to keep within the schedule time. Where fuel was cheap and labor dear, it was found to be economical in the long run to dispense with one train crew, and push the locomotive to the full limit of its power, even if it did vomit black smoke and unburnt coal from the smoke stack. The difference in the cost of labor has had a potent influence in the development of the two types, especially in the past twenty or thirty years. Whereas the Englishman, with his copper fire box, brass tubes, deflector plate and mild exhaust, his inside cylinders, large single drivers, low piston speed, and light loads, was aiming at a high theoretical efficiency, the American, with his four, six, and eight-coupled drivers of small diameter, his big cylinder capacity, large steam ports, his huge boiler with its big heating surface, his roomy fire box and sharp exhaust, was aiming at large hauling capacity. It is sufficient to say that both have reached the goal; and that while the American locomotive will haul three tons to the English two, it will burn more fuel per ton in the effort.

Between 1850 and 1860 the coal burning locomotive became common, and with the advent of coal the brass and copper tubes were discarded for iron tubing, which in turn was to give place to steel. This decade also saw the general introduction of the wagon-top boiler, and the influence of anthracite coal was seen in the long, sloping fire box, as shown in the celebrated "camel backs" of Ross Winans. The next decade saw the building, at the Baldwin works, of the "Consolidation," and the introduction of the Bissel truck, the swing bolster truck, and steel tubing. The two decades 1870 to 1890 were marked by a steady increase in the weight and power of locomotives, and by their classification into

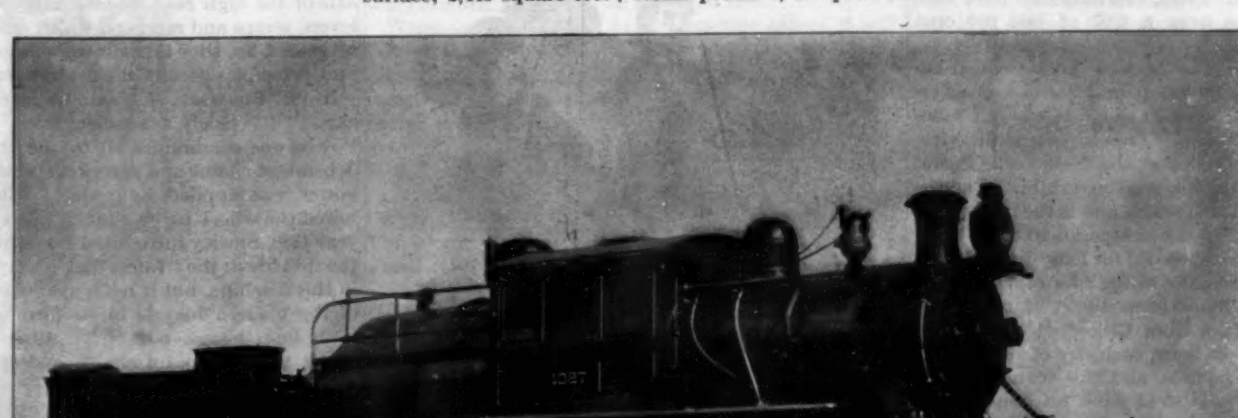


No. 999 OF THE N. Y. C. & H. R. R., 1893.

Cylinders, 19 by 24 inches; drivers, 86¼ inches; weight, 62 tons; steam pressure, 190 pounds. A modern example of an American eight-wheeled express engine. Hauling the Empire State Express, the fastest train in the world; speed, 64·22 miles an hour, excluding stops.

FOUR-CYLINDER COMPOUND DECAPOD FREIGHT LOCOMOTIVE, 1893.

Weight of engine alone, 96 tons; hauling capacity, 4,600 tons; cylinders, 16 inches and 27 inches by 28 inches; heating surface, 2,443 square feet; steam pressure, 180 pounds.



FOUR-CYLINDER COMPOUND EXPRESS ENGINE, 1895.

Weight of engine alone, 71¼ tons; cylinders, 13 by 26 inches and 22 by 26 inches; diameter of drivers, 84 inches; diameter of boiler, 58¾ inches; heating surface, 1,835 square feet; steam pressure, 190 pounds.

distinct types, according to the work for which they were designed.

The year 1888-89 was memorable for the introduction of the compound engine into America. Compounding had already reached a high state of development in Europe, when the Pennsylvania Railroad determined to give it a trial in American service, and to this end purchased an English compound engine, designed and built by Mr. F. W. Webb, of the London and Northwestern Railway. The Pennsylvania, as she was called, was put to work on the company's regular trains and made an excellent record for economy.

Speaking of its performance, a prominent Pennsylvania official said at the time: "I am not at liberty to give exact figures as to the saving of coal shown by the Webb engine over our regular passenger locomotives, but I will say that it has been considerably over twenty-five per cent." The era of compounding, thus introduced, has resulted in its trial on most of the leading roads of the country, and invariably with a showing of large economy. The outside two-cylinder compound has been the favorite type. Two fine examples of the four-cylinder compound are shown in the accompanying cuts of an express passenger, and a heavy Decapod freight, engine, built by the Baldwin works under the Vauclain patents. By reference to the cuts it will be seen that the cylinders are arranged in pairs, the high pressure above the low pressure, the piston rods engaging a common crosshead. Piston valves are used, being placed on the inner side of the high pressure cylinders. The engines shown have the Wootton firebox, designed for burning low-grade coal, the total heating surface of the firebox of the passenger engine being 180¼ feet, and of the freight engine 234¼ feet.

As illustrating the highest development of the simple eight-wheel express passenger engine, we have selected the New York Central engine No. 999, of Empire State Express fame, which is at present hauling the fastest train in the world, and holds a record speed for the mile of something over one hundred miles an hour.

The dimensions of these three engines, together with those of the Lake Shore and Michigan Southern engine No. 564 (Brooks Locomotive Works), to whose phenomenal run we refer later, are given in the accompanying table:

No. of Engine and Name of Company.	Engine and Builder.	System.	Cylinders.	Drivers.	Weight on Drivers.	Total Weight.	Heating Surface.	Steam Pressure.
No. 999. N. Y. C. and H. R. R.R.	Four-coupled express. N. Y. C. and H. R. R.R.	Simple.	19 in. × 24 in.	86¼ in.	84,000 lb.	124,000 lb.	1,930 sq. ft.	190 lbs.
No. 1027. Atlantic City R.R.	Four-coupled express. Baldwin.	Compound.	13 in. / 22 in. × 26 in.	84¼ in.	78,600 lb.	148,000 lb.	1,835 sq. ft.	190 lbs.
No. 564. L. S. and M. S. R.R.	Six-coupled express. Brooks.	Simple.	17 in. × 24 in.	68 in.	88,500 lb.	118,500 lb.	....	180 lbs.
No. 805. L. E. and W. R R.	Decapod freight. Baldwin.	Compound.	16 in. / 27 in. × 28 in.	50 in.	170,000 lb.	192,000 lb.	2,443 sq. ft.	180 lbs.

The Lake Erie freight engine is rated to pull 4,600 tons on the level, and on a run between West Carbondale and Ararat Summit, with a load of 1,107 tons, it consumed 8·28 pounds of fuel per car mile, with a water evaporation of 7·57 pounds per pound of coal. This is a really astonishing performance, when we bear in mind the grades and the loads. From Carbondale to Forest City, 25 cars, weighing in all 818 tons, were hauled for 5 miles over a 1·33 per cent grade; and from Forest City to Ararat Summit, 33 cars, weighing 1,107 tons, were hauled for 13·7 miles over a 0·95 of one per cent grade.

No. 999 is one of the class of New York Central engines which hauled a 361,000 pound train from New York to Buffalo, 436·32 miles, at the rate of 64·22 miles an hour, exclusive of stops. This superb locomotive, which was built at the shops of the New York Central and Hudson River Railroad, was on exhibition at the Columbian Exhibition at Chicago, and is the most popular and widely known engine in America to-day.

No. 564 to-day holds the record for long distance fast runs, having covered 86 miles at the rate of 72·92 miles an hour. This performance formed part of a 510 mile run with various engines from Chicago to Buffalo, at the rate of 65·07 miles an hour, exclusive of stops. The train load was 304,500 pounds, and the 86 mile run of No. 564 included 8 miles at 85·44 miles an hour, and 33 miles at 80·6 miles an hour, with one mile at 92·3 miles an hour. At this last speed the revolution of the drivers was 469 per minute, and the piston speed 1,878 feet per minute! This performance of No. 564 in hauling 152¼ tons for 33 continuous miles at 80·6 miles an hour is unquestionably the greatest locomotive feat that was ever officially recorded. That it should have been done by a six connected 5½ foot driver engine simply proves the value of great boiler capacity and large steam ports.

The growth of the locomotive industry can be best told in figures. In 1846 the Rogers Locomotive Company turned out 17 locomotives; in 1896 their yearly capacity is 300, and they have built 5,150 locomotives in all. In 1846 the Baldwin Locomotive Works turned out 42 locomotives; in 1896 their yearly capacity is 1,000, and they have built nearly 15,000 locomotives to date! It is estimated that to-day there are over 36,000 locomotives in service in America, representing a money value of not less than three hundred millions of dollars.

THE BICYCLE.

Lord Charles Beresford has said, "Whoever invented the bicycle deserves the thanks of humanity." At the present day the bicycle stands unrivaled as a means of healthy exercise and pleasure. The practical uses to which it may be put seem limitless, and now the bicycle is assisting the electric railroad and the automobile carriage to relegate the horse-drawn vehicle to the past. The evolution of the bicycle from the primitive forms has been by a series of positive steps, each step marking a distinct advance in the march of improvement. If for no other reason, the last half century is notable on account of the introduction and development of the bicycle, and nearly the whole history of this evolution falls well within the period we are considering.

THE VELOCIPEDE OF 1868.

It is necessary to go back to the last century for the germ of this great invention, when a strange device called a "hobby-horse" was introduced. It consisted of two wheels connected tandem by a rigid frame of wood. The rider sat on a saddle midway between the wheels and propelled it by means of strides on the ground. Naturally its motion was limited to a straight line. This rigid, non-steering bicycle, propelled by the feet on the ground, was the first step toward the modern machine. The second step was taken in 1818, when Baron Von Drais introduced a vehicle called a "draisienne," which resembled the foregoing machine, but the front wheel was so arranged that steering was possible. That such cumbersome means of locomotion soon fell into disuse is not to be wondered at. For a long time no real progress was made, though various systems and devices were introduced to enable the rider to propel himself, but they were mostly tricycles and were cumbersome and unmechanical. The third step consisted in the invention of a bicycle which was capable of being steered and which was propelled without touching the feet to the ground. This machine was credited to a Scotchman, Gavin Dalzell. The motion of the pedals was downward, the feet describing a small segment of a circle. The motion was transmitted to a crank attached to the axle of the rear wheel by levers. For a long time it was supposed that this invention dated from 1834, but in 1892 a close scrutiny of the matter resulted in the downfall of the legend, as a blacksmith's bill for the iron work was found, which proved that it was made in 1847, and also that another Scotchman named MacMillan had anticipated Dalzell's invention.

TANDEM VELOCIPEDE OF 1869.

It is to Ernest Michaux, a young French locksmith, fourteen years of age, that we are indebted for the next great step which made the modern bicycle possible. In 1855, while repairing a draisienne, he conceived the idea of applying cranks directly to the front wheel. He tried the device for a couple of days and then showed the machine to his friends. The driving mechanism was improved by Pierre Lallement, to whom the credit of the invention is sometimes given, but the French seemed to have settled the matter by erecting a monument to the memory of Ernest and Pierre Michaux at Bar-le-Duc in 1894. The Michaux bicycle or "velocipede," as it was called, attained great popularity. We illustrate a typical example of the machine as improved and ridden by the Hanlon Brothers, taken from an engraving published in the SCIENTIFIC AMERICAN for August 19, 1868. The popularity of the velocipede or "bone shaker" at that time knew no bounds; riding academies were established, races run and the machine even penetrated to the far East. The columns of the SCIENTIFIC AMERICAN of this period faithfully mirror the enthusiasm of the time. In the issue for March 20, 1869, among the "Velocipede Notes," appears an interesting item to the effect that thirty years previously Michael Faraday could be frequently seen driving his machine through the suburbs of London.

In 1869 M. Magee, a Parisian, still further improved the velocipede by making it entirely of iron and steel. In the same year rubber tires were used; these were both important steps in the development of the bicycle. In 1869 M. Michaux conceived the idea of making the front or drive wheel larger than the rear wheel, and various other improvements, such as a brake, were introduced. In 1874 M. Merchegay showed that weight would be reduced by using a large front wheel and a small rear wheel, and that the rider should be mounted directly over the axle of the front wheel. These ideas were carried out, and the popular "spider" or "ordinary" was the result. This machine remained in the ascendency for nearly fifteen years. In 1875 touring became popular, and the bicycle soon showed that it had come to stay. The new wheel weighed from 35 to 50 pounds, against 80 to 100 for the old velocipede. We present an engraving of a wheel of the best type of "ordinary."

There were certain undeniable dangers connected with the use of the high wheel, and accidents were many and serious. At length came signs that the design and construction of the wheel was in a state of transition. Various expedients were adopted to avoid the dangerous "header." The "Star" bicycle became a prime favorite. In this bicycle the small wheel was placed in front and the rider was mounted over the axle of the high rear wheel. They were propelled by levers, straps and ratchets, which enabled the wheel to be geared up, thus introducing one of the most important principles used in the modern machine.

In 1877 Rousseau, of Marseilles, introduced the "Kangaroo," in which a smaller front wheel was used. Power was communicated to the axle by means of independent chains and sprockets, to the latter of which power was applied by pedals; this arrangement allowed the wheel to be slightly geared up. About the year 1880, Starley introduced his famous "Rover." At the first blush the "safety" of to-day is unrecognizable in this machine, but it really embodied the vital points of the modern bicycle in its form. The wheels were both low, though not of the same size, and the rear wheel was driven by chains and sprockets, as in our latest wheels. The great superiority of this machine over the ordinary was soon recognized. Cycling became more popular, and by degrees the high wheel was abandoned by all the makers. The pneumatic tire was the greatest of all the advances since Michaux, and marks the last step in the improvement of the wheel of to-day.

The modern bicycle is distinguished from the older types of wheels on account of the difference in materials, frames and tires. Complex shapes, once thought impossible to produce except by casting, are now forged. Great improvements have been made in brazing together the parts and in cold swaging also, so that the joints are no longer considered the points of weakness.

Great improvements made in the manufacture of tubing during the last few years have rendered it possible to construct a good road wheel which weighs, when complete, only 19 to 22 pounds. By a series of careful

...s on the strength of the material used, the liability of breakage has been greatly reduced. The use of interchangeable parts and automatic machinery has also tended to standardize the product. Great advances have also been made in the rims, and at the present day in this country the heavy steel rim has given place to the wooden rim, which, as now constructed, has considerable strength.

Changes in the frame have been notable. The original Rover frame, which was not strong enough, was soon practically abandoned, and, after a time, the diamond frame took its place. At first, however, the frames were built on dissimilar lines, every manufacturer having a model of his own. Soon the frames of the wheels began to have a general resemblance, and at last the almost universal straight line pentagonal diamond was adopted. Gradually the top bar of this frame was raised until to-day, in the latest machines, it is parallel with the ground. In its frame the bicycle is now a veritable mechanical and engineering achievement. The bearings received more and more attention, until now a wheel with ball bearings will travel thousands of miles without showing any appreciable wear either to the balls or to the bearing cones. There has been a gradual improvement also in the sizes of the wheels; at first even in the modern safety the wheels were of different sizes, but now they are almost universally of the same size. In the old velocipedes, the frame was rigid, then springs were introduced into the saddle and the different parts of the frame, and rubber was introduced into the tires. Then the cushion tire was introduced, which made riding more enjoyable. Finally the pneumatic tire was resurrected from the old patent records, thus furnishing the ideal spring between the rider and the ground, minimizing the jar due to inequalities of the road and giving the maximum of ease and comfort to the rider. In 1845 R. W. Thompson patented in England the first pneumatic tire, but it was only in 1889 that it was adapted to the bicycle by an Irish veterinary surgeon named Dunlop. The cushion tire, in which there was a hollow space in the rubber, was known as far back as 1870, but it became very popular only when the pneumatic tire began to be introduced. It soon succumbed, however, to the pneumatic. It is to the pneumatic tire that we are indebted for a large part of the popularity which cycling now enjoys, and it may be regarded as one of the most important improvements. By these gradual steps the bicycle has been brought to its present state of perfection. An impressionable Italian has well defined the bicycle as "a poem in metal."

In connection with the bicycle, it is necessary to take notice of the tricycle, which was at one time very popular.

The mechanical difficulties connected with the tricycle were less than those connected with the bicycle. The large, cumbersome vehicles which traveled over our streets some years ago are now rarely seen. There appears, however, to be a considerable demand for tricycles built upon the lines of the modern bicycle, and the machines which have been produced within the last few years are comparable in design and workmanship with the bicycle itself. There have been a number of special forms of bicycle, which, from time to time, have been put on the market, and many of which have been very successful. The tandem is the best example of these special forms of bicycle. As far back as April 10, 1869, the SCIENTIFIC AMERICAN published an illustration of a tandem velocipede, which was probably the earliest known example of the tandem. The back seat was intended to be used either as a side saddle for women or a man's saddle. The inventor also had in view the placing of two side saddles over the rear wheel, thus foreshadowing a modern type of special machine. The advantages connected with a tandem are so great that it is little wonder they have achieved a wonderful popularity. Geared up to high speeds, they are able to cover the ground with great ease. Not only are the two riders able to carry on conversation, but the absence of vibration, and the power which it has against a head wind, have all conduced to make the tandem popular. Gradually came the demand for higher and higher speeds; so the number of riders was increased until now, for pacing and racing purposes, we have six or even seven riders mounted on a single pair of wheels. A sextuplette wheel truly represents an engineering achievement, as the truss may have to support a thousand pounds. Such a wheel is geared to 153, so that every revolution of the pedals carries the wheel 38¼ feet.

THE BICYCLE OF 1879.

THE "ROVER" OF 1880.

Ladies' wheels early attracted attention after the safety was in use, and to-day the lady riders are numbered by hundreds of thousands. The lady's wheel presented a more difficult problem than the ordinary bicycle, as the diamond frame was necessarily abandoned. A lady's wheel is now produced of strength equal to that of a man's wheel, with a slight increase of weight. As far back as 1875 we find the Starleys bringing out a high wheel for women. The rear wheel no longer tracked with the driver; it ran upon the end of an axletree which protruded twelve or fifteen inches to one side of the machine, so that a two-track bicycle was the result. This permitted the fair driver to ride side-saddle position. It seems almost impossible that the lady's wheel could be the outcome of this mechanical atrocity, and we may rather look for its origin in the "Rover." The first drop-frame or lady's machine was patented in the United States in 1887.

When it is considered in its economic aspect, it will be seen the bicycle has wrought a veritable revolution, rehabilitating many industries and causing the downfall of others, while travel is diverted into new channels. It is estimated that at present there are 4,000,000 bicycle riders in the United States, while New York City alone possesses 200,000 riders. There are at least 250 reputable wheel manufacturers in the United States, besides a host of smaller concerns that cannot be strictly called manufacturers. Over $60,000,000 are invested in the plants, which give employment to more than 70,000 persons. It is estimated that the wheels turned out this season will exceed 1,000,000. A whole army of workmen are engaged in making bicycle sundries and in repairing. The wheel has brought prosperity to numberless country hotels and road houses which had become almost extinct since the decline of coaching. One great benefit conferred by wheeling is the agitation in favor of good roads. This has been of untold value to the country at large.

"The wheel took a holiday to join in the sport and recreation of men, but the yoke of business is upon it and it cannot escape the bondage. It took the race untold ages to capture the magic circle and harness it to human need, and it is too precious for man to give it a long tether." For many years the cycle has been a plaything of man, but the developments of the last few years have rendered it a valuable aid for business purposes. It makes the slow fast, and now telegraph messengers, postmen, lamplighters, building and street inspectors, "walking delegates," policemen, firemen, coast patrollers, express messengers, doctors, and others are all using the bicycle in their respective avocations. The experiments used to demonstrate the applicability of the bicycle for war purposes have been entirely successful, so that this opens up a new field of usefulness. Bicycles propelled by electricity or one of the petroleum products have been made, but are not in use to any extent.

An eminent physician has said that not within two hundred years has there been any one thing which has so benefited mankind as the invention of the bicycle. Thousands of men and women are now devoting half their time to this healthy recreation and are strengthening and developing their bodies and minds, and are not only reaping benefit themselves but are preparing the way for future generations which will be born of healthy parents; and in brief this epitomizes the hygienic side of the bicycle.

THE PROGRESS MADE IN THE GENERATION OF ELECTRIC ENERGY AND ITS APPLICATION TO THE OPERATION OF MOTORS DURING THE PAST FIFTY YEARS.

The advancement of science during the past fifty years has been so great that many are inclined to believe that we have found out more within this period than all that was known before. While this conclusion may not be strictly correct, there can be no doubt that the value of the principles, the truth of which has been conclusively demonstrated during this period, is greater than that of all discoveries previously made. This is true even of the purely theoretical development of science, but when we come to consider the question of the practical application of the knowlege thus acquired we can, without hesitation, say that the last half of the nineteenth century has not only produced greater advancement than any previous period of equal length, but more than all the centuries that have gone before it.

This may seem an extravagant statement, but any one who will consider the difference between the present state of advancement and the condition of the world fifty years ago will come to the conclusion that it is substantiated by the facts. The steamship, the railroad, the telephone, the telegraph, the electric light, the electric motor, electric railways, and all the numerous collateral industries that have been brought into existence thereby, have been developed within this period. It is true that the telegraph, the locomotive and the steamboat were invented previous to this time, but their reduction to a thoroughly successful form and their extensive practical application has taken place almost wholly since 1845.

Although progress in every department of science has been very great, that which overshadows everything else is the wonderful development of electricity, specially within the last twenty years.

Previous to 1850, this science was in a very crude state. Even the most eminent physicist of those days knew little about the fundamental laws of the subject, and some of them held views that in the light of our present knowledge were absurd in the highest degree.

THE BICYCLE OF 1896.

During the succeeding twenty-five years (from 1850 to 1875) great advancement was made in the way of development of electrical theories, and the demonstration of the laws that govern electro-magnetic actions. Since 1875 the progress has been more in the direction of practical applications of electric energy than in the expansion of theoretical knowledge, and this is just contrary to the general impression in relation to the subject. Any one who has doubts as to the correctness of this statement, however, can have them dispelled by a careful study of the masterly treatise on electricity and magnetism by Prof. James Clerk Maxwell, the first edition of which was published in the early seventies,

This work stands even to-day as one of the foremost upon the subject. There is not a known law or principle relating to electricity or magnetism that is not fully demonstrated therein, unless it may be some action of minor importance. Going back still further, we shall find that nearly all that we know of the theoretical part of the subject at the present time may be found described and in most cases explained in "Faraday's Researches" or the writings of our own immortal Joseph Henry.

The numerous effects of electro-magnetic action were extensively investigated at an early date, but their true relation to each other and to the other forces of nature were not properly understood until the doctrine of the conservation of energy was established upon a firm foundation. Owing to this fact, some of the most distinguished men of fifty years ago advanced views that were decidedly at variance with the facts and only served to assist humbugs in their efforts to defraud investors. The natural result of this was that development was to a certain extent retarded; but considering the great progress that has been made, notwithstanding such drawbacks, we cannot feel that we have much cause for regretting the course that events have taken.

Many of the leading physicists of early days believed that the power of an electric motor could be increased almost without limit by simply reducing the distance between the rotating and stationary magnets. This belief was due to the fact that the weight that a magnet will hold with the armature in actual contact with the poles is very much greater than at a distance of but a small fraction of an inch. On this account it was assumed that accuracy of construction and rigidity of design would greatly increase the energy obtainable from a given amount of electric current. Charlatans at once took up this theory, and when they were unable to demonstrate to their victims that they had produced wonderful results, they restored confidence by saying that the force of the magnets was so great that the whole machine would spring and allow the poles to actually come in contact and thus absorb the power in friction; but that they thought that certain changes they had worked out would get around this difficulty. Such explanations with suitable modifications generally enabled them to obtain several additional subscriptions from the hopeful capitalists; but in the end confidence would be lost, and the plausible inventor would depart to other fields, where a new set of victims could be obtained.

In the course of time scientific men, who were experimenting in the electrical field, found out that the amount of energy that could be obtained from a battery was dependent upon the quantity of zinc decomposed, and that nothing of any account could be gained by reducing the clearance between the stationary and rotating parts of the motor or, in fact, by any change in the design. Having ascertained this much, they began to experiment with a view to discovering new and more economical means for generating the electric current. It was then known that a motor made with permanent steel magnets in the field would act as a generator of current, if driven at a sufficiently high velocity. Machines of this class were first made by Pixii in 1832, the principles of their action having been demonstrated by Faraday about a year previous.

Although J. S. Woolrich constructed a machine of this class of considerable size for those days in 1841, it was not until about 1862 that anything worthy of note was accomplished in this line. In that year Holmes brought out a large machine of sufficient capacity to be used for "arc" lighting, or, more properly speaking, for furnishing current for one "arc" light. This machine generated electric energy at a much lower cost than the electric batteries, but its size was very great in comparison with the work it would do, and its construction was of such a character as to be necessarily very expensive. Several other large machines of this type were designed and constructed during the next three or four years, but owing to their cost and bulkiness did not meet with much favor.

In 1866, Wilde developed a machine which was the stepping stone to the dynamo of the present day, and although the improvements it led to remained practically unused during the following ten years, it can justly be regarded as the step that marks the beginning of the present era of electrical development. Wilde discovered the fact that the current generated by a small magneto machine, if used to energize a powerful electro-magnet forming the field of a larger machine, would enable the latter to develop a current many times greater than that of the small machine. This discovery resulted in directing the attention of scientific men to the subject with renewed vigor. After a careful consideration of Wilde's work the conclusion was arrived at, that if a comparatively small machine could energize the field of a much larger one, that would

THE NEFF MOTOR, 1851.

generate a current many times greater, it ought to be possible to use a part of the current of the large machine to energize its own field, and thus dispense with the smaller machine. But it was also thought that the assistance of the small machine would be required to start the action. By actual trial it was soon found that the larger machine would start a current without the assistance of the small one. Then the conclusion was that all that was necessary was to pass a current through the machine from an external source, when started for the first time, and that the residual magnetism that would remain in the iron ever after would be sufficient to start the generation of current whenever the machine might be set in motion at any future time. It was soon found that initial magnetizing was unnecessary, and then it was concluded that locating the field in a north and south position would enable the machine to start the action by the aid of the earth's magnetism. Finally it was found that no such expedients were necessary; that all iron is magnetic in a slight degree, and that any machine, if properly constructed, would build up a current as soon as set in motion.

One of the most extraordinary facts in connection with the dynamo is that it was in existence and was used by the greatest physicist of all countries for thirty years or more before its properties were discovered. As far back as 1834, Jacobi constructed an electric motor with electro-magnets in both the field and armature. This machine was a dynamo, and if driven in the opposite direction to that in which it ran as a motor, it would have generated a current. The action would have been very feeble, because the commutator was so arranged that it would not allow a continuous current to circulate through the machine. Nevertheless, the action would have been sufficient to have been detected. But all the motors with electro-magnetic fields made between 1834 and 1866 were not of this class. In all probability more than half of them reversed the current through the armature coils. Such was the arrangement used by Davenport, who constructed, in 1837, the first experimental electric railway.

Any of the electro-magnet motors in which the current was reversed would have generated a current so strong, if they been rotated backward, that its presence could not have escaped notice. Yet hundreds of theses machines were experimented with for more than a quarter of a century, and the fact was never discovered.

Facts like this only serve to show how shortsighted the human intellect is, even that which is located in the brains of the most eminent men.

Between 1866 and 1876 very little was done in the way of practical development, but quite considerable in the way of improving the dynamo. In the machine of Wilde and several others that immediately followed it an armature was used that gave a pulsatory current. Gramme made an improvement in this direction by adopting a ring-shaped armature, upon which the wire was wound in a great many sections, the ends of which were attached to a commutator of a corresponding number of sections. As a result of this construction the current was rendered far more uniform, and the destructive sparking of the brushes was practically eliminated. Siemens, also, worked in this line, and accomplished the same results by the use of a drum-shaped armature. A few machines of both these types were introduced for the operation of "arc" lights, but their introduction was at a very slow pace.

In 1876 and the two or three following years, storekeepers in the large American cities began to realize that the electric "arc" light was very valuable for advertising purposes. This at once increased the demand for lights, and resulted in the establishment of central lighting stations. In the early eighties [these stations had become very numerous, and the electric lighting industry had attained considerable inportance. In the mean time the incandescent light had been reduced to a commercial success, and was being rapidly introduced.

Up to this time very little was done in the way of utilizing electricity for the transmission of power. This was due principally to the fact that it was not believed that electric motors could compete successfully with steam engines, inasmuch as they would have to be operated by currents generated by the energy of the latter, and therefore would cost much more to run, not only on account of the loss in the conversion and reconversion of mechanical into electrical energy, but also on account of the profit that the central stations would have to make to yield a fair return upon the capital invested in the generating and distributing plant. As at that time it was very generally believed that the dynamo could not be made very efficient (some placing the theoretical limit at fifty per cent), this belief was almost universal. But at about this time it was beginning to be clearly demonstrated that the efficiency of the dynamo could be made very high. It was shown theoretically that those who claimed fifty per cent as the limit of efficiency were misled by mixing the law of maximum work with that of maximum efficiency. The truth of these theoretical arguments was demonstrated by the actual performance of the best machines that were then being made, in some of which an efficiency approximating ninety per cent was obtained.

When it became fully demonstrated that the efficiency of dynamos could be made very high, the future of the electric motor ceased to be so hopeless. It was then realized that the difference in coal consumption between large and small engines would go far toward offsetting the losses in the generation and transmission of the electric energy and in paying the profits of the central station, and that the small excess in cost of electric power would be largely if not wholly compensated for by the convenience, compactness, and many other advantages of the electric motor. On this account the introduction of these machines began to be pushed with greater vigor than previously. Unfortunately most of the first inventors who entered the motor field were not very well informed in electrical science, and as a result nearly all the early machines were defective electrically as wel

SIEMENS ELECTRIC LOCOMOTIVE OF 1879.

... rude mechanically. This circumstance served only ... etard the development of the electric motor.

... 1884 and 1885, more able men began to turn their ... ntion to this field, and from that time up to the present day, the growth of the electric motor has been very r...d.

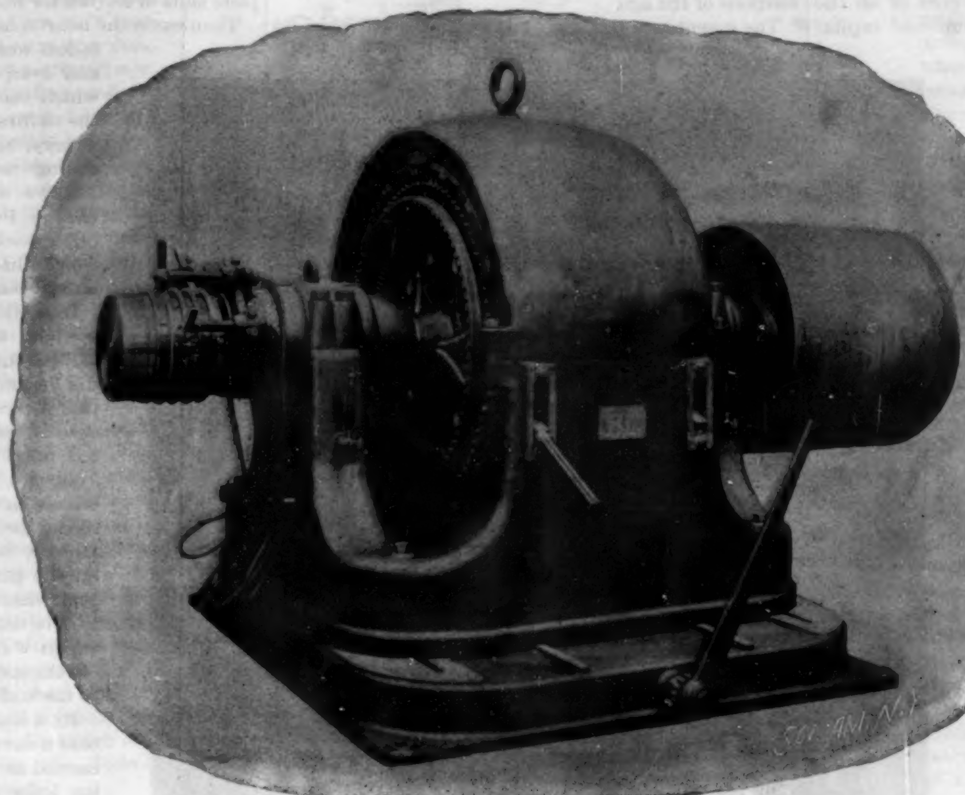
... first these machines were used for the operation of s...ll printing offices and for driving coffee mills, ventila...ng fans, sewing machi...es, etc. Soon after they w...e used to operate pumps a...d also freight elevators in warehouses. This led to the development of regular electric elevator machines, which came about in 1888. Although an electric pump, in the truest sense of the word, cannot be said to have been developed so far, there are many combinations of motor and pump now that are a great improvement on those used ten years ago.

One of the greatest triumphs of the electric motor has been in the street railway field. As every one knows, a substitute for animal power on these roads had been looked for for many years. Steam, compressed air, gas, hot water, and other systems were tried, but without success. The cable proved satisfactory on large roads with heavy traffic, but was not regarded as a complete solution of the problem, because it was too expensive for small roads.

The possibilities of the electric motor in this field were realized even before its practicability in other directions became demonstrated. In 1879 Siemens constructed an experimental electric railway which actually carried passengers. Several others worked in this field during the following years, but it was not until about 1888 that complete success on a commercial scale was attained. The electrical equipment of all the street railways of Richmond in that year, and the complete success of the installation, was the real beginning of the introduction of electricity for the operation of railways. From that time up to the present day, horse roads, in towns and cities throughout the United States, have been changing over to the trolley system as fast as the apparatus could be obtained from the manufacturers. The electric railway motor has found its way into almost every quarter of the civilized world, but nowhere to such an extent as in this country; in fact, the development of electricity in every line has been carried much further here than in any other part of the world.

When electricity began to invade the railway field, it was believed by many that the storage battery would become an important adjunct; but those who had such hopes have been doomed to disappointment so far, and it is probable that such will continue to be their fate. The storage battery of to-day is not adapted to railway work. Future improvements may, and probably will, enable it to compete successfully with the trolley in isolated cases, under certain conditions, but it is safe to say that it is impossible for it to ever become a formidable rival.

One direction in which electric motors have made great headway, and about which the general public knows little or nothing, is in mining, especially coal mining. Coal-cutting machines operated by compressed air have been used for many years; these are now being equipped very generally with electric motors.



THREE HUNDRED HORSE POWER TWO-PHASE ELECTRIC MOTOR.

Mining pumps, hoisting machines, and ventilating plants are operated electrically. In addition to these may be mentioned mine locomotives, of which a large number are in use.

The extent to which electricity is used in mining may be judged when it is said that it is estimated that the capital invested in such apparatus aggregates over one hundred million dollars.

In considering the development of the electrical industry, we are accustomed to say that it has been brought about within the last twenty years; but as a matter of fact nearly nine-tenths of it is the outgrowth of the last fifteen years, and the development of the electric motor branch has occurred within the last ten years. At the convention of the National Electric Light Association held in Detroit, in August, 1886, a paper was read on the subject of electric motors; and to show the extraordinary growth of the industry, it was stated that at that time fully five thousand were in use. To-day it is estimated that over five hundred thousand are used, or a hundred times as many as ten years ago. But this difference in numbers does not represent the full difference; for of the five thousand motors in use in 1886, at least four thousand were of the size used for driving small fans and sewing machines. At that time a ten horse power motor was considered very large, and it is doubtful if there were more than fifty in operation throughout the entire country. To-day there are numerous machines of over one hundred horse power, and some even five or six times that capacity. There are several large manufacturing establishments where over three hundred motors are in use, their aggregate power running in some cases beyond four thousand horse power. Concerns that use one hundred or more motors, requiring for their operation from one thousand horse power upward, are quite numerous.

Some idea of the difference between the machines of to-day and the efforts of the early experimenters, in design as well as magnitude, may be obtained by comparing the illustrations of the earlier motors and locomotives with the later ones. The motor invented by Jacob Neff, of Philadelphia, is a fair representation of the electric motor of forty and fifty years ago. The armatures, which were plain bars of iron, were held by the frame of the motor while the electro-magnets were carried by a hub on the shaft journaled in the center of the frame and carrying a commutator for directing the current through the several magnets in succession as their poles approached their armatures. The two-phase electric motor here illustrated is a machine of to-day. This is a Westinghouse 300 horse power motor of the self-starting induction type, designed to operate at a speed of five hundred revolutions per minute when supplied with two-phase currents of 3,000 alternations per minute and 2,000 volts pressure. This machine affords an example of the latest development in electric motors. The Siemens locomotive of 1879, under guidance of the motorman, is here figured and one of the one hundred ton locomotives now in use in the Belt line tunnel of the Baltimore and Ohio road at Baltimore is shown. These locomotives are more powerful than the largest steam locomotives.

A few figures will show the extent of the electrical industry in the United States at the present time.

In the mining industry it is estimated that the investment in electric apparatus amounts to over one hundred millions.

The estimated number of motors

ONE HUNDRED TON ELECTRIC LOCOMOTIVE, 1895.

Used in the Belt Line Tunnel of the Baltimore and Ohio Railroad at Baltimore.

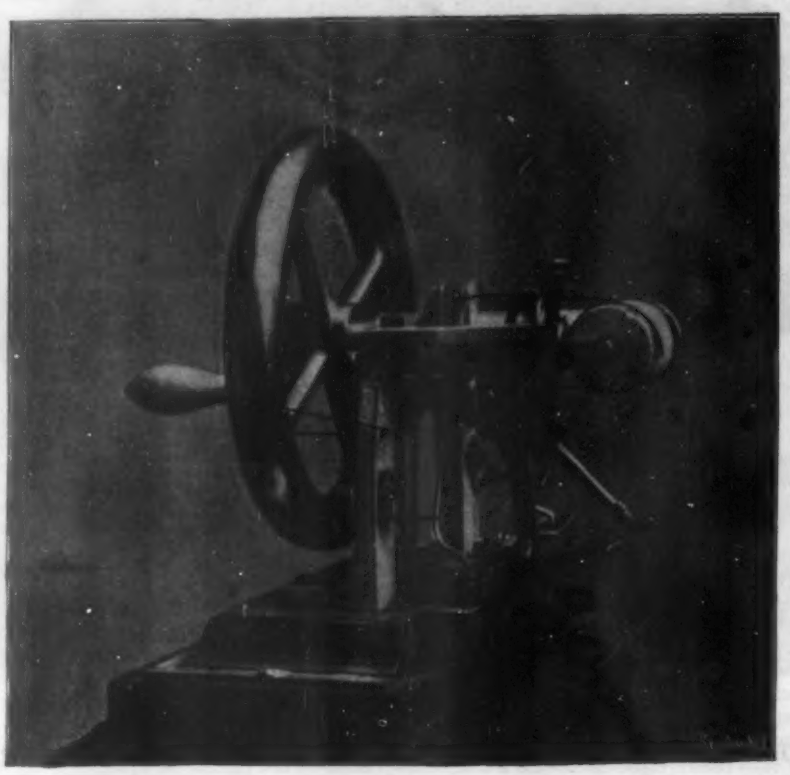
in use is five hundred thousand; placing the average value of these at one hundred and fifty dollars, the aggregate represents seventy-five millions. The number of electric elevators in use is not known, but as there are over six hundred in New York City alone, it is evident that the total must run up into thousands, and represent an investment of ten or fifteen millions.

There are over twelve thousand miles of electric railroads, using over twenty-five thousand trolley cars. This represents more than ninety per cent of all the street railways in the country. The combined capital of these roads is over seven hundred millions. There are over twenty-seven hundred central stations, from which light and power are furnished. The investment is this line is over three hundred millions. There are nearly eight thousand isolated plants, valued at more than two hundred millions.

These several industries represent a total investment of nearly fourteen hundred millions, of which nearly two-thirds is invested in those branches in which the electric motor, in one form or another, is used. This two-thirds of the industry has been developed within the last ten years.

It is estimated that nearly four per cent of all the people in the United States make their living in one way or another out of the electric industry.

As an indication of the manner in which we have outstripped European countries in the electric field, we may mention the fact that there are over eight times as many electric railways in this country as in all the rest of the world combined.



THE ELIAS HOWE MACHINE, SEPTEMBER 10, 1846.

Earliest model filed in Patent Office.

THE SEWING MACHINE.

Fifty years have passed since Elias Howe applied at Washington for a patent on his sewing machine, and placed on file the working model which is herewith illustrated. On the tenth day of September, 1846, the patent was granted. That day may justly be written down as the birthday of the sewing machine—the practical modern machine as we know it to-day—and the year 1896 is therefore the semi-centennial anniversary of one of the greatest labor-saving devices of modern times.

In according to Elias Howe the title of father of the sewing machine, one is not unmindful of the earlier attempts of other inventors, whose devices, more or less crude and impractical, contained a suggestion of the future combination of parts, which was to make possible mechanical sewing. The records of the English Patent Office show that on July 17, 1790, Thomas Saint patented a sewing machine, which had a horizontal cloth plate, a vertical reciprocating needle, a continuous thread fed from a spool, an automatic feed and means for tightening the thread. It sewed with a chain stitch, an awl forming the hole, and a needle with a notch in its lower end pushing the thread through the cloth, and forming the loop. Thimonnier, in 1830, patented a machine in France, in which a barbed needle, shaped like a crochet needle, was carried through the material from above, and caught a thread which was on the lower side, bringing it up through the cloth, and forming a chain stitch on the upper side.

THE WILSON MACHINE OF NOVEMBER 12, 1850.

Earliest model filed in Patent Office.

Walter Hunt, of New York, applied for a patent in 1854, and showed that in 1834 he had made and sold sewing machines which embodied an eye-pointed needle and a shuttle. Whatever success Hunt may have had with these designs, it is certain that it was not until Howe had independently invented his own machine, and proved its utility to the public satisfaction, that Hunt thought his device of sufficient importance to cover it with a patent. His application was rejected "on the ground of abandonment," the courts holding that the patent law is framed for the protection and reward of such inventors as disclose their inventions for the public benefit. If Hunt's machine was practical, as he claimed, we have here a notable instance of the folly of allowing a useful invention to lie dormant until some independent inventor has achieved the same result, and demonstrated its commercial value. Similar cases to this of Hunt and Howe are not far to seek. They all teach us that, if the first inventor believes his device to be practical and valuable, he should hasten to place himself beneath the protection of the patent law; but that if he loses faith in its possibilities and value, and gives up his search, he should be content to leave the field to others and "for ever hold his peace."

Whatever credit may be due to the early machines above mentioned, and to the later experiments of Hunt, the fact remains that Elias Howe did independently invent a practical sewing machine, which contained the three essential features of a needle with the eye at the point, a shuttle operating beneath the cloth to form the lock stitch, and an automatic feed; that he had sufficient faith in his machine to cover it with a patent; and that his unconquerable perseverance enabled him to convince the world of its commercial utility and establish its reputation as one of the most beneficial inventions of the age.

The inventor of the sewing machine was born in 1819 at Spencer, Mass. His father was a farmer and miller, whose means were so small that Howe was put to work at bread winning when he was yet a mere child. At twenty we find him a machinist in the shop of a Mr. Davis, of Boston, Mass., where he was first started on his investigation of the possibilities of mechanical sewing by hearing a capitalist remark to his employer that a large fortune awaited the man who could invent a sewing machine. At the outset he lost much valuable time in the endeavor to copy the motions of sewing by hand. If young Howe had known something of the early attempts of Saint, Thimonnier and others, he would have given his sewing machine to the world some years earlier than he did; but he had to go over the road that others had traversed before him, trying in vain to sew successfully with a needle pointed at both ends, and having the eye at the center. It was in 1844 that he abandoned the attempt to imitate the hand stitch, and conceived the idea of using two separate threads, on either side of the cloth, and forming the stitch by the co-operation of a shuttle. He was on the right track at last, and it was a natural step to shift the eye from the center to the point of the needle, so as to more readily form the loop for the passage of the shuttle. He did this, and in October, 1844, by means of a rough model, he had satisfied himself that his device would sew. Howe was very poor, and in spite of the priceless secret which lay hidden in his brain, he found himself quite unable to purchase even the material to build a working machine. Fortunately for him and the world at large, he was able to induce a former schoolmate, George Fisher, to provide $500 for the expenses of constructing a machine, and to board Howe and his family while it was being built, in consideration of which he was to acquire a half interest in the patent when it should be taken out. The work was finished by April, 1845, and in July he sewed two complete suits of clothes for himself and Fisher.

Then came the heartache and disappointment. The tailors were suspicious of the machine; and even after a public exhibition, in which the machine easily beat five of the swiftest sewers of a clothing manufactory, he received not a word of encouragement.

Howe went back to the garret of George Fisher's house and built another machine, for deposit in the Patent Office, this being his second machine and the one shown in our illustration.

In all the annals of the Patent Office it would be difficult to find a "stronger" patent than this. So completely did it embody the essential features, that it carried its author safely through such a tempest of litigation as never fell upon a patentee before or since. Judged by comparison with later machines, the product of skilled and intelligent mechanics, this early effort of Howe's, with its piece of cloth stuck on the pins of a "baster plate," is a somewhat clumsy affair; but it sewed, and it did so according to principles which will probably continue to govern the construction of sewing machines to the end of time.

By a study of the cut it will be seen that a curved, eye-pointed needle was carried at the end of a vertical vibrating lever, and that it took its thread from a spool situated above the lever. The tension on the thread was secured by means of a spring brake, whose semicircular ends bore upon the spool, the pressure being regulated by a vertical thumb screw. The work was held in a vertical plane by means of pins projecting from the edge of a thin metal "baster plate," to which an intermittent motion was given by the teeth of a pinion. Above the "baster plate" was the shuttle race, through which the shuttle, carrying the second thread, was driven by means of two strikers, which were operated by two arms, and cams located on the horizontal main shaft.

After securing his patent, Howe, discouraged by his reception in America, determined to introduce his machine in England, and sent one over by his brother, Amasa B. Howe, to London, where a Cheapside manufacturer of corsets agreed to furnish money to promote the new venture. The following year, 1847, we find Howe in London trying, as part of the bargain, to adapt his machine to the sewing of corsets. Then followed two years of heartbreaking failure, in the course of which the inventor sank steadily into poverty. From three small rooms, he moves into one in the poorest part of Surrey. He borrows from a chance friend the means for bare existence, and the money to send his sick wife to America. Then he finishes a machine worth $250, which he sells for $25; and finally he pawns his first machine and his patent for money to carry him back to America, where he arrives, practically penniless, in April, 1849.

From this time on the tide of fortune sets steadily in his favor. He discovers that in his absence his shuttle machine has been built and sold freely in America, and that the mechanical world is waking up to its great possibilities. With the assistance of his father he commenced an infringement suit against those parties who were making his machine, or machines embodying his claims, and after a bitter fight he came off completely victorious. A vigorous attempt was made by I. M. Singer & Company to break the Howe patent, on the ground that an earlier machine (as already mentioned) had been made by Walter Hunt; but while the parts of the Hunt machine of 1834, which were recovered and produced in court, showed that he was "upon the track of the invention," the evidence showed that he had finally given up in despair of any practical results. In 1854, Judge Sprague, of Massachusetts, in giving a verdict for Howe, observed that "there is no evidence in this case that leaves a shadow of doubt that, for all the benefit conferred upon the public by the introduction of a sewing machine, the public are indebted to Mr. Howe." His success in the Singer suit was followed by

a verdict against other infringers, and they were obliged to pay royalties, (at first $25 on each machine), which in themselves ultimately gave him a princely income. He also established a factory in New York, and, having bought up the remainder of his patent, he commenced to manufacture his own machine. His patent was extended for seven years, in 1860; but another application, in 1867, was denied. He was decorated with the cross of the Legion of Honor by France, in 1867, and died on October 3 in the same year.

Next to Howe, the name of Allen B. Wilson claims notice as the inventor who has done the most to give us the present perfected sewing machine. To him we are indebted for those two most ingenious and beautiful pieces of mechanism: the rotating hook and the four-motion feed. He claims to have conceived the idea of a sewing machine in 1847. His first machine was built during the spring of 1849, while he was in the employ of a Mr. Barnes, of Pittsfield, Mass., a cabinet maker. In the same year he built a second and better machine, and "up to this time," says, "I had never seen or heard of a sewing machine other than my own." He sells a one-half interest in the invention to Joseph N. Chapin, of North Adams, and with the proceeds takes out his first patent, which bears date November 12, 1850. The model of this machine, now in the Patent Office, is shown in the accompanying illustration. It formed a lock stitch by means of a curved needle on a vibrating arm above the cloth plate, and a reciprocating two-pointed shuttle traveling in a curved race below the plate. The feed motion was obtained by the two metal bars which are seen intersecting above the shuttle race. The lower bar, called the feed bar, had teeth on its upper face, and by means of a transverse sliding motion it moved the cloth, which was placed between the two bars, the desired distance, as each stitch was made.

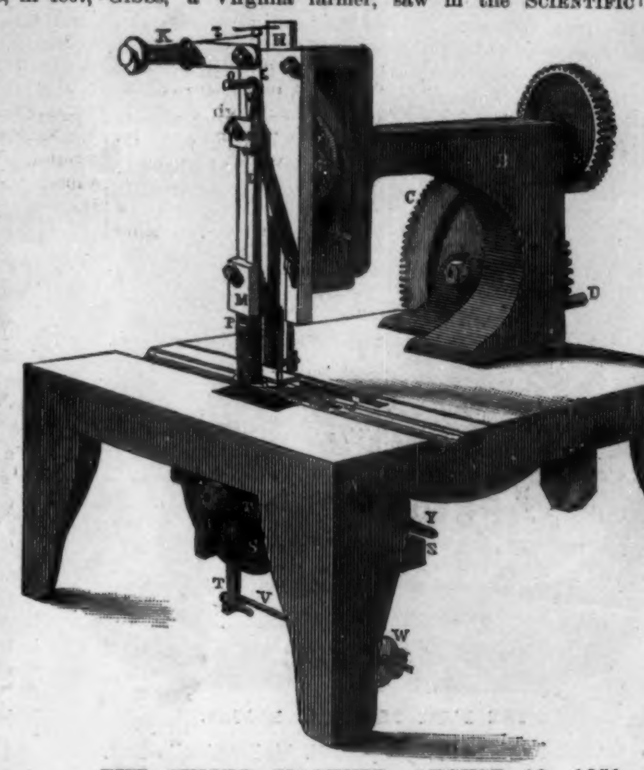
In 1851 Wilson patented his famous rotating hook, which performs the functions of a shuttle by seizing the upper thread and throwing its loop over a circular bobbin containing the under thread. This simplified the construction of the machine by getting rid of the reciprocating motion of the ordinary shuttle, and contributed to make a light and silent running machine, eminently adapted to domestic use.

In 1852 Mr. Wilson patented his four-motion feed, which, in combination with a spring presser foot, may be said to form the basis of all modern feeding mechanisms. The feed bar, as its name indicates, had four distinct motions, two vertical and two horizontal. It was first raised by the action of an eccentric on the driving shaft, then carried forward by a cam formed on the side of the eccentric (by which operation the work was shifted the desired distance), then it dropped, and finally it was drawn back by a spring to its original position. This machine, as shown in our engraving, uses the curved needle and embodies the rotating hook and the four-motion feed. The latest type of this machine uses a vertical needle bar and a straight needle.

Wilson had the good fortune soon after securing his patent to interest Nathaniel Wheeler, a young carriage maker who possessed some capital, in his machine, and out of this connection grew the great house of Wheeler & Wilson. Unquestionably, the association of Mr. Wheeler with the sewing machine at the very inception of the industry was very largely answerable for its early and rapid success. It is rarely that the inventive and the commercial instinct are combined in the same man. It is certain they were not in Wilson. Wheeler, on the other hand, was eminently qualified by his wisdom, tact, and engaging presence to promote the interests of the new device. He succeeded in interesting some of the wealthy capitalists of the day, and the successful career of the Wheeler & Wilson establishment is a tribute to his undoubted business ability.

In 1851 W. O. Grover and W. E. Baker patented a machine which made the "Grover & Baker stitch." They used two needles, one above and the other below the material, the lower needle passing horizontally through the loop of the upper thread and producing a double chain stitch on the under side of the cloth. Great things were hoped from the double chain stitch by its promoters, and in the first twenty years its yearly sales rose to over 50,000; but, while it is specially adapted to certain classes of work, it has never won the popularity of the shuttle lock stitch.

To Mr. James E. A. Gibbs the world is indebted for the single thread rotating hook machine. Mr. James Parton, in his historical review of this industry, written in 1871, says: "Twelve years ago, Mr. James E. A. Gibbs, a Virginia farmer, saw in the SCIENTIFIC AMERICAN a picture of a sewing machine. The working of the apparatus was very plain down to the moment when the needle perforates the cloth, and he fell into the habit of musing upon the course of events after the point of the needle was lost to view. The result of his cogitations, aided by infinite whittling, was the ingenious little revolving hook, which constitutes the peculiarity of the Willcox & Gibbs machine." The rotating hook, which is placed below the cloth plate, seizes the loop, and during the ascent of the needle, it gives a twist to the thread, and spreads it out beneath the needle hole ready for the next descent of the needle, when the hook catches another loop and repeats the operation.



THE SINGER MACHINE, AUGUST 12, 1851.

Earliest model filed in Patent Office. Reproduced from the SCIENTIFIC AMERICAN of November 1, 1851.

Patent No. 8294, of August 12, 1851, introduced one of the most useful machines, and one of the most remarkable men, that have figured in the development of the sewing machine. Isaac Merritt Singer, strolling player, theater manager, inventor, and millionaire, brought into the business a new machine and novel methods of exploitation, which gave a powerful impulse to the youthful industry. The Singer improvements met the demand of the tailoring and leather industries for a heavier and more powerful machine. Our illustration shows the original machine upon which the patent of 1851 was granted. The novelties consisted in the circular feed wheel below the cloth plate, which had a serrated periphery projecting slightly above the plate, and was fed by a rock shaft and pawl; a thread controller; and the use of gear wheels and shafting to transmit the power from the hand wheel to the two countershafts for working the vertical needle and the shuttle. Singer was also the first to introduce foot power in place of the hand-driven crank wheel. He was a man of astonishing energy and fertility of resource, and he was the originator of the system of sale by agents, which has done so much to introduce the sewing machine into the domestic circle.

Before passing on to a consideration of the statistics of the sewing machine, mention should be made of the application of this remarkable invention to the shoe and leather industries, where it has worked something like a revolution. The hand sewing of the uppers has given place to the quicker work of the machine; and this in turn led to the invention of the justly celebrated McKay machine for sewing on the soles of shoes, which was first introduced in 1861. According to Mr. Frederick G. Bourne, president of the Singer Manufacturing Company, "it is stated that as many as 900 pairs of shoes have been sewed on one machine in one day of ten hours; and that over 350,000,000 pairs of shoes have been made on the McKay machine up to the year 1877 in the United States, and probably an equal or greater number in Europe." This machine used a waxed thread and made a chain stitch. The Goodyear, a later machine, makes the lock stitch with a waxed thread, and sews on the sole in the same way as it is done by hand.

One could wish to dwell at length upon many of the remarkably ingenious applications of the sewing machine to the various trades, and make mention of the glove stitcher, the buttonhole machine, and many others, but we must pass on to general statistics.

In 1856 the owners of the original sewing machine patents formed the famous "sewing machine combination" for the establishment of a common license fee, and for the protection of their mutual interests. The combination included Elias Howe, the Wheeler & Wilson Manufacturing Company, the Grover & Baker Sewing Machine Company, and I. M. Singer & Company. Any manufacturer who had a machine with reasonable claims to novelty was admitted on payment of the license. The records of this combination furnish us with valuable statistics of the sewing machine industry up to the year 1876, when the patents expired; an extract from these records is given below:

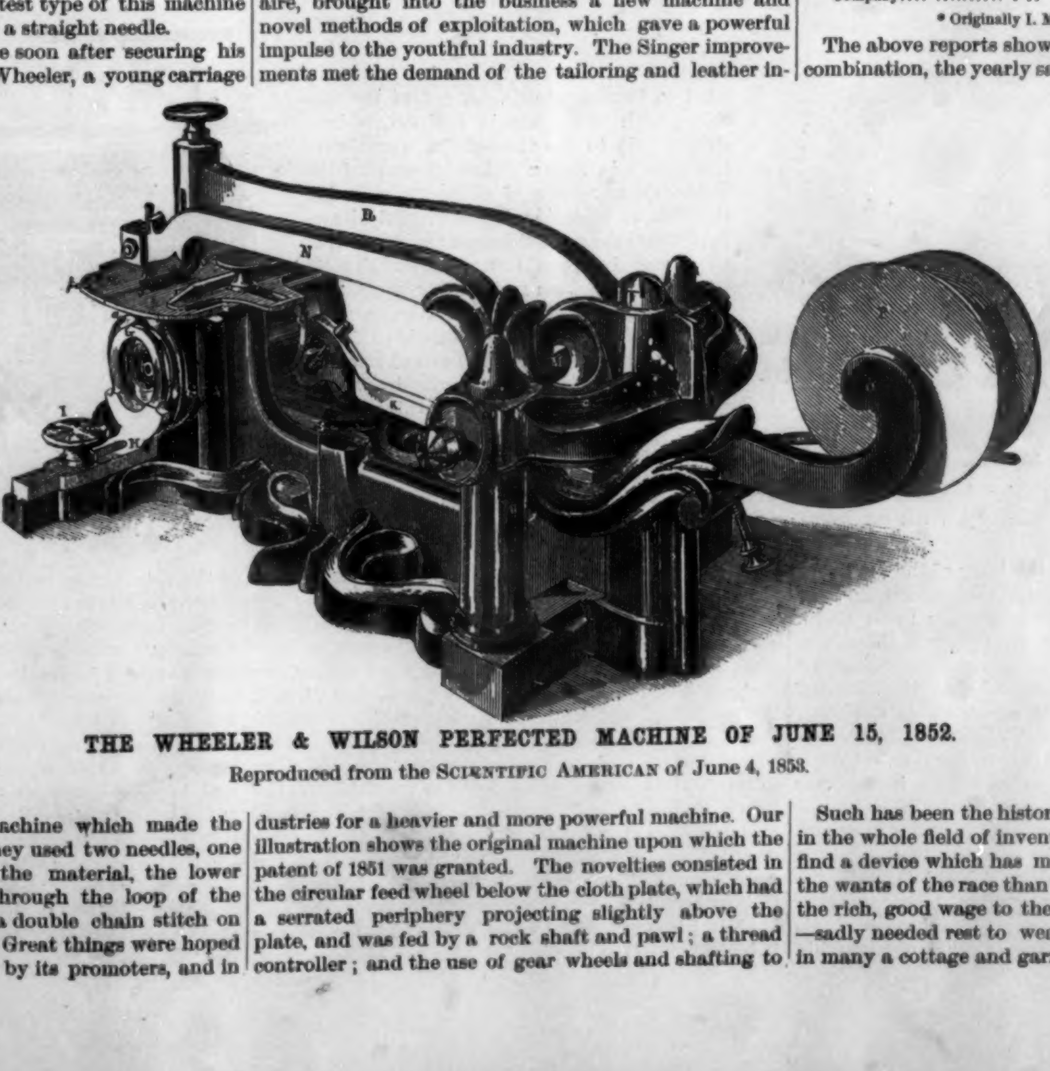
Manufacturer.	1853	1859	1867	1871	1873	1876
Wheeler & Wilson Manufacturing Company........	799	21,306	38,055	128,526	119,190	108,997
*The Singer Manufacturing Company..............	810	10,953	43,053	181,260	232,444	262,316
Grover & Baker Sewing Machine Company........	657	10,280	32,999	50,838	36,179	......
Howe Sewing Machine Company........	....	....	11,053	134,010	90,000	109,294
Willcox & Gibbs Sewing Machine Company.....	....	....	14,159	30,127	15,881	12,758
Domestic Sewing Machine Company....	....	....	....	10,397	40,114	23,587

* Originally I. M. Singer & Company.

The above reports show that, in the last years of the combination, the yearly sales of machines in the United States averaged 575,000! The subsequent census reports further indicate that the annual sales during the next fourteen years averaged over half a million; and a canvass which we have recently made of the leading firms in the United States shows that the yearly output in 1896 may be put down at between 600,000 and 700,000.

Furthermore, the records of the Bureau of Statistics show that the total value of the exports of sewing machines from 1865 to 1895 reaches the large sum of $67,000,000.

Some conception of the patient investigation, intelligent thought, and time and money that have been spent in perfecting the sewing machine may be had from the fact that from 1842 to 1895 over 7,000 patents had been granted on its various modifications!



THE WHEELER & WILSON PERFECTED MACHINE OF JUNE 15, 1852.

Reproduced from the SCIENTIFIC AMERICAN of June 4, 1853.

Such has been the history of the sewing machine, and in the whole field of invention it would be difficult to find a device which has ministered more intimately to the wants of the race than this. It has brought gold to the rich, good wage to the worker, and—best gift of all—sadly needed rest to weary fingers and aching eyes in many a cottage and garret.

AGRICULTURAL MACHINERY.

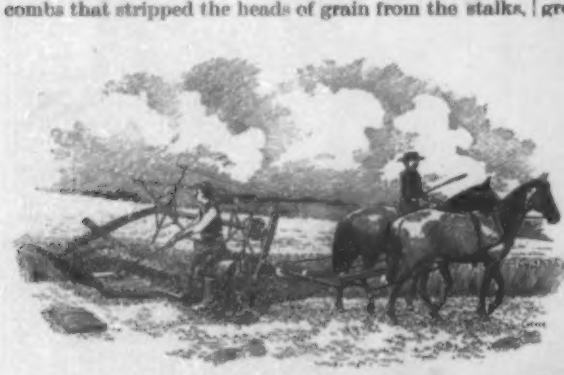
Before the building of the reaper it could be truly said that those who earned their bread by the labor of the harvest did so by the sweat of their brows. In the heat of midsummer, without protection from the beating sun, in a stooping position, the toilers of the world gathered the harvests. So excessive and trying was the labor that the wages at harvest time were double those of other seasons of the year, and the farmer engaged his help months in advance for this rushing period.

A little more than half a century of American invention in harvesting machinery has worked wonders as great, and has contributed as much to the wealth and prosperity and the civilized progress of the world, as has the spinning jenny and power loom in manufactures and the railroad in transportation.

The modern self-binding harvester is drawn into the field in the morning, and by night twenty acres are cut and bound into bundles with cord bands and left in windrows for convenience in shocking. This machine does the work of twenty men and does it better, saving enough grain over hand labor to pay for the cord used in making the bands. To such an extent has the industry of producing these machines progressed that 150,000 machines of this type are produced yearly, the manufacturers in the city of Chicago alone turning out more than three-fourths of this number. They are sold world wide, and every self-binding harvester contains as its fundamental elements the inventions of American artisans and mechanics. The scythe has given way to the mowing machine, and the extreme labor of the harvests and the crowds of extra help are seen no more on the farm.

The number of mowers annually produced exceeds the number of self-binding harvesters, and while they are not such savers of labor, still each machine does the work of five men with scythes. A conservative estimate of the number of self-binding harvesters that will be in use in the harvest of 1896 would be 400,000, and more than that number of mowing machines. In no country are these machines used so universally as in America, and the tremendous effect of their use in the production of grains and stock can scarcely be realized. The agricultural prosperity of the land depends upon them. The great prairies of the West were only developed by their aid. It is only by their use that the American farmer can compete with the myriad hordes of cheap laborers in the old world, and close students of the political history of our country lay the preservation of the Union to the fact that the reaper allowed the gathering of the harvests, and the progress and development of the Northwest, to proceed during the time of the great rebellion.

It takes but a few years beyond a half century to include the invention and building of the first practical reaper, and the important steps of improvement that have taken place upon it to develop it into the effective modern machine of to-day. At the beginning of the century there was no reaping machine. The Royal Agricultural Society of England at that time offered a prize for the production of a successful reaper, and continued this offer for forty years. The carts that the ancient Romans used on the plains of Gaul, that were pushed ahead of the ox and which were fitted with combs that stripped the heads of grain from the stalks, causing the heads to fall into the body of the cart, were not machines, inasmuch as they had no gathering, severing, or automatically operating devices upon them. However, in all history, down to the year 1828, these carts are the only practical operating devices mentioned for gathering grain. In 1828 an Englishman, Rev. Patrick Bell, built a machine that did some work in the field. It was used for a few years and discarded. After the first World's Fair, which was held in London in 1851, it was, however, revived and changed so as to incorporate ideas from the American machine on exhibition at this fair. Even with the added features it was not a success, and soon disappeared from the market.



THE McCORMICK REAPER OF 1845.

The first step in the progressive development of the reaper was the placing of the raker upon the machine.

In 1831, Cyrus H. McCormick, of Virginia, built the first practical grain harvesting machine. It contained the essential elements that have been found in every grain harvester that has proved a success from that day to this. Looking back upon the work of the last sixty years in the department of reaping machines, it will be seen that thousands of ideas have been advanced. Almost every known mechanism has been tried for severing, gathering and handling the cut crop, but through all this time and all these experiments the machines that have contained the elements invented and arranged as in the first machine built by Cyrus H. McCormick have been the only ones that have been of use in the real labor of the grain harvest. The first machine had a main wheel frame, from which projected to the side a platform containing a cutter bar, having fingers through which reciprocated a knife driven by a crank; upon the outer end of the platform was a divider projecting ahead of the platform to separate the grain to be cut from that to be left standing; a reel was positioned above the platform to hold the grain against the reciprocating knife, and to throw it back upon the platform, and the machine was drawn by a team walking at the side of the grain. This machine was the first to contain these elements, which have invariably been embodied in every grain harvesting machine made from that day to this. They are the essential elements of a reaper, without which no grain harvester can be built. This machine was successfully operated on the farm of John Steele, near Steele's tavern, Virginia, in the summer of 1831. In 1833 Obed Hussey built a machine and operated it in the field. It was similar to the McCormick machine, except that it had no reel and no divider. It also had no platform upon which the cut grain could accumulate and be raked to one side out of the way of the path of the wheel in the next round of the field. These two machines were operated year by year down to 1845, and were the only machines up to that time that were capable of successfully harvesting grain.

THE FIRST PRACTICAL REAPER.

Invented and built by Cyrus H. McCormick in 1831.

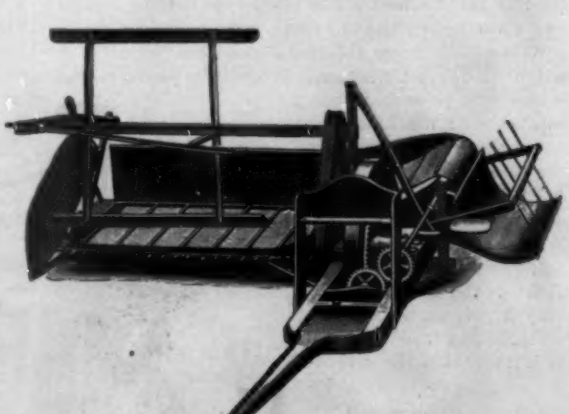
The first step of importance in the development of the practical reaper of 1831 was the addition of the raker's seat, which McCormick invented and applied to his machine, a device by which the raker could be carried upon the machine and as he rode through the field rake the grain from the platform to the ground, whenever sufficient grain had accumulated to form a bundle. A cut of the machine, with the raker in position, is here shown. Up to the time of the invention of the reaper, in 1831, a diligent search of the Patent Office records of all countries, and of the files of scientific journals, agricultural papers and mechanics' magazines, shows that there was but one German, two French, twenty-three British and twenty-two American inventions referred to, and but a small number of these were patented. Of this number but one machine survived a test in the field, and it has been shown by the experience of half a century that this machine (the Bell) did not contain the essential elements necessary for the production of a successful reaper.

In the early days of the use of harvesting machines the reaper was used to cut grass, or as a mower, and in 1849, A. J. Purviance, of Ohio, obtained a patent for the removing of the platform of the reaper, so that the grass when cut by the knife could pass back over the finger bar upon the ground, and the machine was thus more conveniently made a combined machine, or one that could both reap and mow. In the spring of 1851, McCormick placed his reaper on exhibition at the World's Fair at London. Hussey also had his machine on exhibition, and they were the only reapers there shown. The machines were tested in the field, and the Grand Council medal, which was one of four special medals awarded for marked epochs in progress, was awarded the McCormick. The judges at that fair were reminded that other efforts had been made toward building reapers twenty years before, in England, but they referred to the McCormick machine as being worth to the people of England "the whole cost of the exposition." When the machine was put into the field for trial it astonished all who saw it operate, and from this exhibition of the reaper, made at great labor and expense by Cyrus H. McCormick, dated the introduction of the reaping machine to the people of all lands. At a later exposition, after again winning the Council medal, Mr. McCormick was decorated by the French government as an officer of the Legion of Honor for "having done more for the cause of agriculture than any living man."

The next progressive step in the development of the reaping machine was the application of an automatic mechanism to rake the grain from the platform to the ground. This work had, up to this time, been done by a man riding upon the machine. In 1849 Jacob J. and Henry F. Mann, of Indiana, patented a machine having a series of endless bands for carrying the grain, after it had been cut and reeled upon these bands, to the side of the machine, where it accumulated in a receptacle until a sufficient amount had been gathered to form a bundle, when the operator dumped the receptacle, leaving the gavel upon the ground.

In 1850 Homer Atkins, of Illinois, invented a device for giving a reciprocating, intermittent motion to a rake, in order to deposit the grain upon the ground, after it had been cut and reeled upon the platform. This machine marks the beginning of an era of self-raking reapers, that continued to be supplied to the market for twenty years. The self-raking reaper was the principal type of a grain harvester in use for more than a quarter of a century, and there were many improvements of minor importance made upon it, such for instance as the quadrant platform of Palmer & Williams, in 1851; the supplementary frame of Densmore, in 1852; the dropper platform of Lucomb, in 1855; the Dorsey continuously revolving reel raking device, in 1856; the Hubbard self-rake, the Wood platform rake; the Whitely improvements in reel rakes; the McClontock Young revolving reel gatherers, carrying a rake revolving around the reel shaft; the Burdick, Howard Dodge, Whitely and Miller improvements in rakes—all of which served their purpose in forming distinctive types of machines to cut and deliver grain in gavels on the ground. They were all attached to reapers whose principles were the same as those invented and built by Mr. McCormick in 1831, and which the Paris Exposition of 1865, in awarding him the grand medal, the highest honor, stated was for "the real inventor of the system which has insured in practice the success of the new implement which is now available for agriculture." After the expiration of Mr. McCormick's patent, in 1848, manufacturing establishments started in different sections of the country, and the building of harvesting machines became a great industry.

In certain sections of the country, however, particular types of machines were used, such, for instance, as a machine called the "Header." Such a machine was patented in 1849 by Jonathan Haines, of Illinois. It had the essential elements of the reaping machine, but was pushed ahead of the horses, cutting a wide swath and clipping the heads of the wheat, which were carried



THE MANN HARVESTER OF 1849.

The second step in the development of the reaper was in applying to it an automatic device to remove the grain therefrom in gathers.

to the side of the machine on endless aprons and deposited in wagons driven at the side of the machine, and by these wagons carried to stacks. This machine was used in considerable numbers in dry countries, and has remained in use in limited numbers even to this day. In the summer of 1850 Augustus Adams and J. T. Gifford, of Elgin, Ill., built probably the first hand binding harvesting machine. It was a machine of the same type as that built by the Manns, in 1849, but it had, in place of the receptacle into which the cut grain fell as it left the traveling apron that conveyed it to the side, a platform upon which men were carried through the field, and upon which the grain fell from the endless apron, where it was bound by men carried upon the machine. This is probably the earliest example of a machine which afterward came into extended use under the name of hand binding harvester. But little was

done with this machine by Mr. Adams, who afterward associated with him one Philo Sylla. In 1853 they built another machine upon which men bound as they rode, but which differed from the first machine in that it had a jointed cutter bar. Up to this time all machines that had been built had a stiff bar extending from wheel to wheel. In 1854 Cyrenus Wheeler, of New York, built a machine for cutting grass, that contained the jointed bar feature of the Adams & Sylla machine, and put into practical shape for the first time the modern form of the jointed bar mowing machine. Louis Miller, of Canton, Ohio, in 1858 made an invention that was an improvement in general form and construction upon this type of a machine. The Aultmans, with whom Miller was connected, had bought before this time the Sylla & Adams patent, and controlled for some years the building of jointed bar mowers and reapers.

In 1858, C. W. and W. W. March, of Illinois, invented their harvester. It was a machine of the Sylla & Adams type, as the grain after it had been cut and deposited upon an endless apron was carried to one side of the machine to men riding upon the machine, who bound this grain into bundles. It should be remembered that the self-raking reaper was the machine in general use up to this time, and men did the binding, walking from gavel to gavel. The Marsh Brothers thought that two men riding upon the machine could do as much work as four walking upon the ground, and their machine, which they continued to develop and perfect for several years, had finally, in 1864 and 1865, been got into shape so that it was practically operative. A cut of this machine is here shown, and it is interesting not only as marking a progressive step in the development of harvesting machines, but as furnishing the machine to which the automatic binder was successfully attached.

The next step in the progress of development toward the modern self-binding harvester was the attachment of a binding device to the reaping machine, to take the grain that had been cut and raked into gavels and bind the same automatically into bundles. John E. Heath, of Ohio, was the first to submit his ideas on the way to form a binder, to the Patent Office. He did this in 1850. In 1851, Watson, Renwick & Watson, skilled theorists, some of whom had been connected with the Patent Office in Washington, filed an application for a self-binding harvester. The specification was very long, and they endeavored to include in it all the ideas they could think of that might possibly be some time worked into an automatic self-binding harvester. No machine of the kind was built by them, and this patent is an example of thousands of devices that have been submitted for patent, which would have been impractical if put into operation. In 1856, C. A. McPhitridge, of St. Louis, filed an application for a patent, which, as we look back over the art, with the knowledge gained from years of experience in the field, is seen to have contained ideas approaching some that are now practical. Probably the first to complete a binding attachment that was partly automatic, and to attach it to a reaping machine, were H. M. and W. W. Burson, of Illinois.

In 1860, the Bursons had some wire binding attachments attached to reaping machines, and in 1863 they built one thousand machines. They were not, however, automatic machines, being assisted by hand labor, and did not do enough of the work to be profitable. In 1864, Jacob Bethel, of Rockford, Illinois, obtained a patent for a very important invention in binders. He showed and claimed for the first time the knotting bill, which loops and forms the knot, and the turning cord holder for retaining the end of the cord. He, however, did nothing more with his invention. Sylvanus D. Locke, of Janesville, Wisconsin, during these years was working upon a wire binder. He took out many patents, and in 1873, after associating himself with Walter A. Wood, built and sold probably the first automatic self-binding harvester that was ever put upon the market. The different builders of reaping machines were at work at this time perfecting automatic binders which they were attaching to harvesters of the Marsh type, by removing the platform upon which the men stood, and placing the automatic binder so as to receive the grain as it is delivered from the elevator of the harvester. S. D. Carpenter, of Madison, Wisconsin, James F. and John H. Jordan, of Rochester, N. Y., Spaulding, of Rockford, and Withington, of Janesville, did good work in the development of the automatic binder that bound with wire. The use of wire, however, as a binding material met with opposition, and the inventors turned their attention to perfecting an attachment that would bind with cord; and to Marquis L. Gorham, of Rockford, Illinois, who built a successful cord binder and had it at work in the harvest field in 1874, must be given the credit of producing the first successful automatic self-sizing binder. It bound with cord and produced bundles of the same size. It was like McCormick's reaper—a machine that contained the essential elements that have been found in every grain binder since its time. The grain in this machine is delivered by the elevators of the harvester upon a platform, where it is seized by packers, working alternately at the center of the grain, and carried forward, wisp by wisp, into a secondary chamber, where it is compacted by the packers against a yielding trip, so that when sufficient grain is accumulated, the trip would yield and start the binding mechanism into operation. The cord is carried on the machine in a ball, one end of which is threaded through the needle and fastened in a holder. The grain is forced against this cord by the packers, and when the binder starts the needle encircles the gavel, carrying the cord to a knotting bill of the Bethel type, and the end is again seized by the rotating holder, the loop formed, the ends of the band severed, and the bundle discharged bound from the machine, at which time a gate, which has during the binding operation shut off the flow of grain, retracts, and the operation is again repeated. This is the plan of operation of every self-binding attachment that is made even to this day. The grain is cut and delivered upon the apron by the devices that McCormick combined and arranged more than half a century ago. It is carried onward and upward to a deck binder by Marsh's plan, and selected from the continuous swath and formed into gavels, which are bound and delivered by Gorham's plan. The most ingenious inventors of the world have, after twenty years, failed to devise a better plan. In 1879, John F. Appleby took out a patent on a machine upon which he had been working for the past four years, which in the arrangement of the devices was an improvement to that of Gorham. It, however, contained the principles of the Gorham machine, which he had seen in operation in the field before he began to work upon his twine binder. The modern twine binder is in the form of its devices and the arrangement of its parts built upon the Gorham plan, as improved by Appleby.

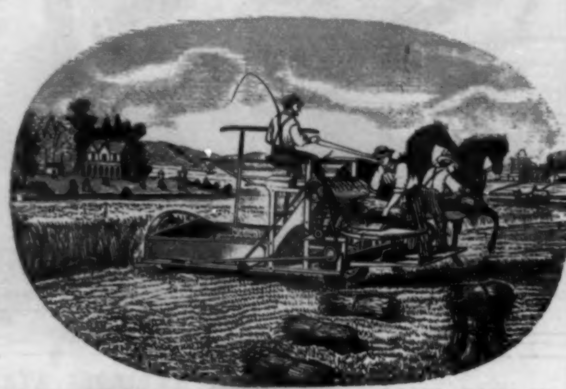
It may be stated that there is a machine built and in practical operation in the dry climate of California that cuts, binds, thrashes and sacks the grain by a single operation. These machines are, however, useful only in very dry climates and are made only in limited numbers, perhaps fifty being built and sold each year. The plan upon which they are built was described in an application for a patent to H. Moore and J. Hascall, Kalamazoo, Mich., June 28, 1836.

The work of the pioneer who enters a new field in invention and develops a new machine is one requiring the greatest persistence, endurance and faith in the ultimate success of the undertaking. In reapers not only did the machine have to be made capable of successfully doing its work, but being a field machine that was to be drawn over the rough fields of the average farm, and handled by all classes of men, and removed long distances from places of repair, it had to be capable of standing hard knocks of every description, simple, easily understood, and difficult to get out of repair. Not only did Mr. McCormick, as the pioneer inventor, have to design a tool of this kind from the foundation, but he had to educate the people to an understanding of the possibilities of his invention, and to the advantages to be derived from its use. Historians have eulogized the pioneers that pressed ahead into the wilderness, among savage Indians, and there cleared farms and made themselves homes, and opened the country for settlement. But the toils and struggles and privations that these pioneers overcame cannot be compared to the years of thought, experiment and toil, the disappointments, the lack of resources and the discouragements that surround an inventor who enters a new field of invention. Mr. McCormick invented his reaper in 1831, and worked with it until 1840 before making a single sale; during the years 1841, 1842 and 1843 those reapers that he made at the home farm in the small blacksmith shop were placed with difficulty, even though they did remarkable work, and showed a great saving in labor. The farm laborers of the country were adverse to them, and threatened any farmer who sought to use one.

As an example of the toil that was necessary to get agricultural machines into the field, it is known that Mr. McCormick made machines in Virginia which were carried over the mountains by team from Lexington to Richmond, and thence by canal to the ocean, by vessel to New Orleans, and up the Mississippi River to distributing points at Cincinnati, Louisville, Dubuque and St. Louis. Being without means, his endeavors to induce manufacturers to produce his machines were time and again failures, and it was not until he had gone personally, on horseback, among the farmers of Indiana, Illinois, Ohio and Kentucky, and obtained from them written orders for his machine that he induced a firm in Cincinnati to manufacture them. It was then necessary to follow these machines into the field, to instruct the farmer in their operation, and to warrant them to give satisfaction, and to remove every possibility of any loss to the purchaser before they could be finally induced to pay for them. This course was continued by Mr. McCormick with unremitting toil for several years, until the reputation of his reaper had spread over the land.

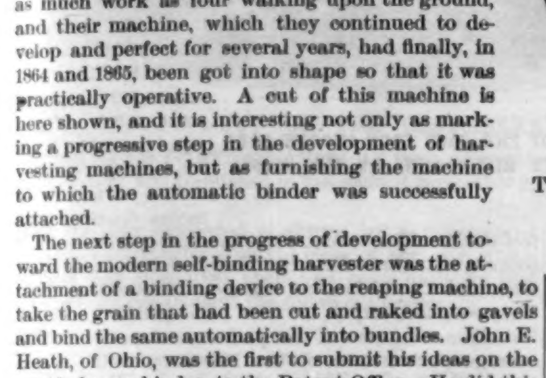
It was then that the usual vicissitudes that surround an inventor who has a valuable invention began to annoy him. Infringers began manufacturing his machine without authority. He began suits; his patents were attacked; interferences were arranged against him, and day by day he saw the grant made him by the government expiring and his returns from it being eaten up in endeavoring to protect his rights. Through all this, so great was the tenacity and so strong was the faith of Mr. McCormick in his reaper, that he took it to the first World's Fair, held at London in 1851, and there astonished the world with its operation. Those who had been the most sarcastic in deriding the invention became the loudest in its praise.

There are but few statistics obtainable in relation to the growth of the industry of manufacturing grain and grass cutting machinery. In 1840 there were three reapers made, and less than that number of people were necessarily employed upon them. In 1845, 500 machines were made, on which 50 people were employed, but not steadily. In 1850, the production had increased to 3,000, and in 1855 to 10,000, employing more or less steadily 500 people in their manufacture, with as many more agents and salesmen to get the machines upon the farm. In 1860 the output had increased to 20,000 machines annually, and there were more than 2,000 people employed in the industry. During the next ten years, the increase was not so rapid, but in 1870 the annual production was about 30,000, and 5,000 people were engaged in the industry. In 1880 this output had increased to 60,000, and 20,000 people were engaged in the industry. About this time the automatic cord binder was perfected, and the next five years showed a marked increase in the output. In 1885 there were more than 100,000 self-binding harvesters built and sold, 150,000 reapers and mowers, and 30,000 people were engaged in the various departments of the industry. 1890 showed another marked increase in production, but not so large as would have been the case had all the different harvesting machine com-



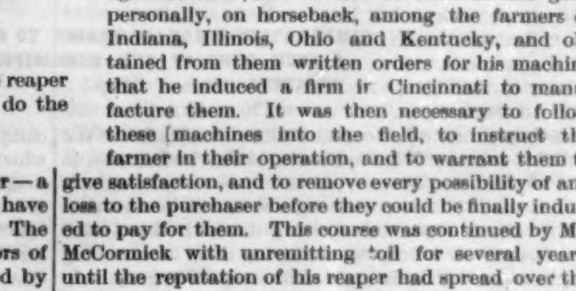
THE MARSH HARVESTER OF 1860.

The third step in the progressive development of the reaper was the placing of men upon the machine to do the binding.



THE LOCKE WIRE BINDER OF 1873.

The fourth step in the practical development of the reaper was the placing of an automatic device upon the machine to bind the grain.



THE MODERN AUTOMATIC, CORD, GRAIN BINDER.

A machine which cuts, binds and carries the bound bundle into windrows.

panies continued the same proportion of increase in their output as did several of the larger ones. In this year two manufacturing establishments in the city of Chicago made more than 200,000 machines, half of which were binders, and the other half mowers and reapers, and these two institutions alone employed in their various branches of manufacturing and selling 10,000 employes. In 1895 the output of the largest of these manufacturing establishments in the city of Chicago was 60,000 self-binding harvesters fitted with bundle carrier and trucks; 61,000 mowers, 10,000 corn harvesters and 5,000 reapers. The number of employes materially increased, but the total number of employes in the business has not increased for the last few years.

There were exported in the year 1880 about 800 self-binding harvesters, 2,000 reapers, and 1,000 mowers. In 1890 this advance increased to 3,000 self-binding harvesters, 4,000 reapers, and 2,600 mowers. The Argentine Republic, Paraguay and Uruguay take most of the machines that go to South America, and perhaps one-quarter of the total exports are to these countries; another quarter goes to the colonies of Australia and New Zealand, while the remainder go largely to the Continent of Europe, where they harvest the grains along the banks of the Red Sea and the Volga in Russia, along the Danube, in France, and in Germany, Sweden, Norway, England and Scotland. From these figures it will be seen that the great user of the labor-saving device is the American farmer. It is only by employing these labor-saving implements that he is enabled to compete in grain raising with the hordes of cheap laborers of India, and with those on the plains of Russia.

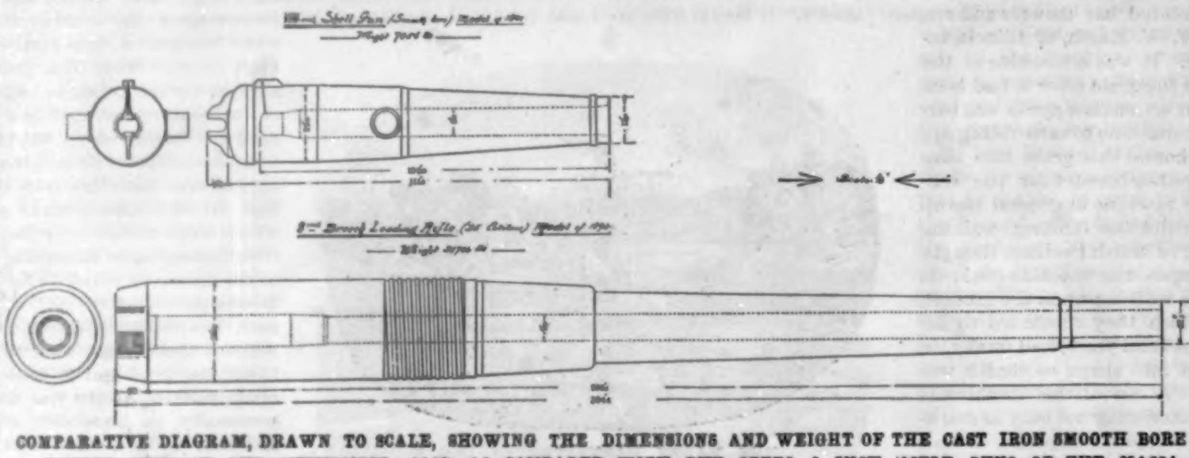
NAVAL AND COAST DEFENSE.

The student of the past half century of progress in naval construction in the United States is tempted to exceed the further limits of his subject. As, in the history of the steam merchant marine, he cannot refrain from mention of the Savannah, so, in tracing the development of the steam warship, he is constrained to go back to the time of the war of 1812 and record the fact that it dates from that year. It appears that, in spite of the splendid service which was being rendered by the navy during the course of that war, it was felt that the sea coast and harbor defense was insufficient, and as a measure of protection to the city of New York it was decided to build a powerful battleship which should rely mainly upon steam for its propulsion. A committee of the Coast and Harbor Defense Association of that day appointed Robert Fulton as engineer, and from his designs a large coast defense steam battleship of 2,475 tons was built and launched on June 20, 1814. According to the plans of the Fulton, as she was named, the paddle wheel was in the center, between what appear to have been practically two hulls, with the boiler in one hull and engine in the other. On her trial trip she made a speed of 5½ miles an hour with her armament on board. As originally designed, she was to have carried 32 heavy guns. Such was the first war steamer the world ever saw. Like the Savannah among transatlantic steamships, she was the pioneer of her class, and she anticipated by several decades the general introduction of steam into the navy.

The progress of the American navy during the past half century has been strangely intermittent, and it may be defined as a long stretch of comparative stagnation, relieved by periods of sudden and remarkable activity, in which the resourcefulness and inventive genius of the nation were shown to be merely dormant. The first awakening came in the great civil war; the second in the last decade—1886-1896—of the period of which we are treating, in which a new navy, comprising ships of the very latest type, has been placed at the nation's service.

Fifty years ago the United States navy was mainly composed of line-of-battle ships and frigates, some of which carried the scars and the glory of many a hard fought duel in the war of 1812. The Naval Register for 1846 gives the following summary of the number of vessels in the navy at that time: Ships of the line, 11; razee (Independence), 1; first-class frigates, 12; second-class frigates, 2; sloops of war, 23; brigs, 8; schooners, 6; steamers, 11; storeships and brigs, 4; a total of 78 vessels of all classes. Of the battleships, the most important was the grand old Pennsylvania, a giant for those days, of 3,241 tons and 120 guns, built in 1837. She had a full complement of 1,100 officers and men and cost $694,500 to build and equip. The other battleships were much smaller, being of about 2,600 tonnage and carrying 84 guns. The frigates of 1,726 tons carried 50 guns and the sloops of war averaged about 800 tons, carrying from 16 to 24 guns. The armament of these vessels consisted of from four to twelve 8 inch guns and from sixteen to seventy-two 32 pounders, according to the size of the ship. All of the guns were smooth bores, firing round shell.

The appearance of nearly a dozen steamers upon the register reminds us that we are dealing with the period which witnessed the passing of the sailing ship. During the next fifteen years, which intervened before the outbreak of the civil war, only half a dozen sailing vessels were built, as against 33 steam warships. In addition to the service rendered by steam to ocean navigation in the merchant service, in the navy it brought further advantages of a tactical nature, which rendered it of special value. As compared with the sailing frigate, the steam frigate was independent of the wind and could place herself in the best position for a fight, giving or accepting battle as she pleased. This alone was sufficient to sound the doom of the grand old wooden two and three-deckers, with their towering topsides and lofty stretch of glistening spars and snowy canvas.



COMPARATIVE DIAGRAM, DRAWN TO SCALE, SHOWING THE DIMENSIONS AND WEIGHT OF THE CAST IRON SMOOTH BORE 8 INCH GUNS OF THE MISSISSIPPI (1846) AS COMPARED WITH THE STEEL 8 INCH RIFLE GUNS OF THE MASSACHUSETTS (1896).

The accompanying illustration, from a daguerreotype of the Mississippi, shows rig and general appearance of a war steamer of 1846. She was launched in 1841, and in 1853 C. B. Stuart, the chief engineer of the navy, speaks of her as having been altogether the most useful and economical side wheeler in the navy. Her dimensions were: Length, 220 feet; beam, 40 feet; moulded depth, 39 feet; tonnage, 1,692; displacement, 3,220. There were two side lever condensing engines, with cylinders 75 inches diameter by 7 feet stroke. The boilers, three in number, were built of copper, with three furnaces, double return, ascending flues, and a total heating surface of 6,000 square feet. They weighed, empty, 120 tons. The paddle wheels, 28 feet diameter, were of the plain radial pattern. The average performance of the Mississippi under steam alone during an aggregate of 30 days was as follows: Speed, 7¼ knots an hour; revolutions, 10·65 per minute; steam pressure, 10⅜ pounds; coal consumption, 37 tons per day. The hull cost $306,683 and the machinery $243,571. She was armed with two 10 inch smooth bore guns, mounted on pivots, one on each bow, and eight 8 inch smooth bores, mounted in broadside abaft the paddle box. The range, penetration, etc., of these guns were as follows:

Gun.	Charge.	Projectile.	Initial velocity.	Penetration through seasoned white oak at			
				500 yds.	1000 yds	1500 yds	2000 yds
10 in....	10 lb.	120 lb. shell.	1,160 f. s.	32·1 in.	24·2 in.	18·2 in.	13·7 in.
8 in....	9 lb.	51 lb. shell.	1,500 f. s.	33·0 in.	23·0 in.	15·9 in.	11·0 in.

The above penetration of 33 inches through oak would be equal to a penetration of 3 inches through iron. This was the maximum performance of the guns of those days. To-day the penetration at 500 yards of the heavy guns carried by our ships has increased from 3 to 30 inches, an impressive evidence of the growth of heavy ordnance.

At the opening of the civil war the fleet of sailing ships consisted of 10 ships of the line, 10 frigates, 20 sloops, and a dozen brigs, store vessels and receiving ships. The steam fleet included 7 screw frigates built in 1855, namely, the Niagara, of 12 guns and 4,580 tons, and 6 of the Roanoke type, of 40 guns and 3,200 tons; 6 first-class screw sloops of 13 to 25 guns and 1,446 to 2,360 tons; 4 sidewheelers of 9

THE MISSISSIPPI—UNITED STATES WAR STEAMER OF 1846.

Displacement, 3,220 tons; speed, 7¼ knots; armament, two 10 inch and eight 8 inch smooth bore guns; total broadside, 324 pounds.

to 15 guns and 1,446 to 2,450 tons; 8 second-class screw sloops of 3 to 6 guns and 694 to 1,289 tons; 5 third-class screw steamers of 5 to 8 guns and 500 tons; 4 third-class sidewheelers of 1 to 3 guns, 450 tons, and 2 screw steam tenders, making a total of 52 sailing and 36 steam warships. Considering the magnitude of the conflict and the vast stretch of coast line and rivers upon which it was to be waged, this fleet was altogether inadequate, and the government strained every nerve by building and by purchase to increase its strength and efficiency.

How far they succeeded is shown by a government inquiry made shortly after the close of the war, which showed that since 1861 there had been built by and for the navy department the following vessels:

54 screw sloops of..................	500 to 3,200 tons and	4 to 21 guns.
36 double-ended sidewheelers....	825 " 974 "	6 " 12 "
8 " " " " (iron)	1,030 "	6 " 10 "
9 tugs........................	350 "	2 "
2 "	170 "	2 "
2 seagoing casement ironclads..................	5,090 and 3,486 "	16 and 18 "
2 seagoing single turret ironclads..................	3,295 " 3,033 "	2 "
5 double turret ironclads....	1,564 "	4 "
4 " " "	970 "	4 "
[illegible] " "	585 to 1,034 "	2 "

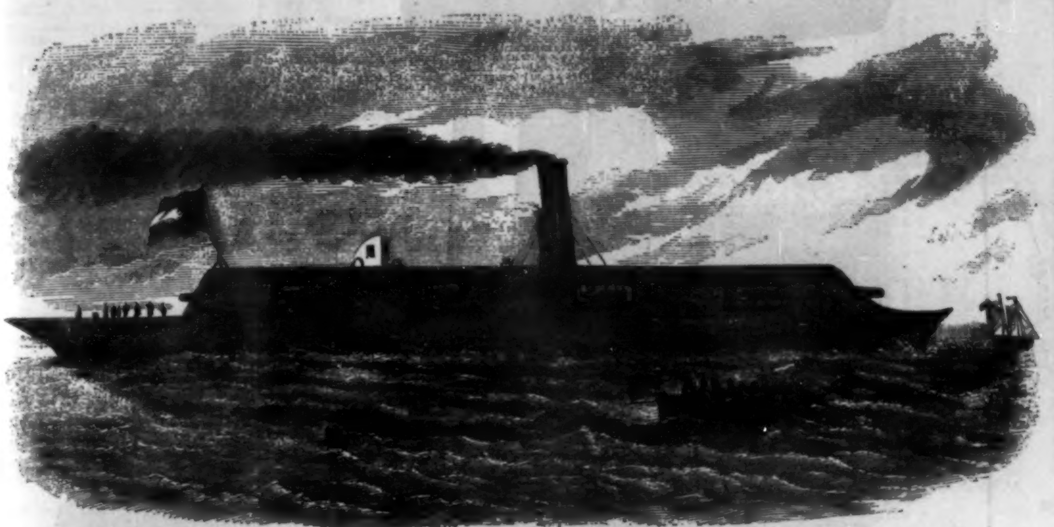
10 other vessels of smaller size and various types.

In addition to the above there were purchased for the navy 497 vessels, ranging in size from 100 to 1,200 tons. To this must be added what is known as the "stone fleet," comprising 44 vessels of 300 tons, 12 canal boats and 22 schooners; these were purchased to be filled with stone and sunk for the obstruction of channels, etc.

In seeking for the birthplace of the modern battleship we are carried back to the European war of the Crimea in 1854, and the American civil war of a few years later. The former gave us the first practical application of side armor; the latter the first actual test of the revolving turret. On October 17, 1855, the French contingent of the allied fleet dispatched three armorplated ships against the Russian forts at Kinburn, and after a stubborn resistance, during which "the steady clang of the enemy's shot upon the" four inch "plating echoed like the blows of a cyclopean sledge-hammer," the forts were silenced, and these little 1,400 ton ironclads came out of the fight victorious, and practically unharmed. But while it is true that this was the first practical test of the ironclad, it is but just to mention the fact that to Mr. Stevens of New York is due the credit of having commenced the construction of an armored floating battery in the United States as far back as the forties. In 1841 he wrote a letter to the Naval Harbor Defense Board, proposing to build a warship which should embody the following features—an iron hull, inclined side armor, engines and boilers below the water line, high pressure steam, the screw propeller, and rifled wrought iron guns, loading at the breech. This remarkable letter formed the basis of a subsequent contract. Limits of space forbid a more detailed description of this ship; but the letter with cuts of the vessel will be published in a subsequent issue of the SCIENTIFIC AMERICAN SUPPLEMENT.

At the outbreak of the civil war the South realized that, with its very limited means for naval construction as compared with the North, it could only hope to prevail by adopting some special type of ship. This conviction led to the reconstruction of the Merrimac, a forty-gun steam frigate of 3,500 tons. She was partially burnt and sunk at the Norfolk navy yard by the United States officers at the opening of the war, to prevent her falling into the hands of the enemy, who subsequently raised her, and finding the hull and machinery in good order, determined to convert her into a side-armored battleship. Her upper works were cut down to the water line, and a rectangular casement, with sides inclined about 35 degrees, was built amidships. The sides were formed of 20 inches of pine and 4 inches of oak, and were covered with two layers of 2 inch iron plating.

The plates, 8 inches wide, had been rolled at the Tredegar Foundry, Richmond, from old iron rails. The first layer was placed horizontally and the second vertically, the whole being secured to the backing by 1⅜ inch bolts. The ends of the casement were rounded, and the roof was formed by an iron grating. Her armament consisted of two 7 inch rifled guns pivotally mounted fore and aft on the center line. On the broadside were two 6 inch rifled guns and six 9 inch smoothbore Dahlgren guns.



CUT OF THE CONFEDERATE IRONCLAD MERRIMAC.

Drawn for the SCIENTIFIC AMERICAN from descriptions furnished by a mechanic who assisted in her construction, and published in the issue of November 9, 1861. Probably the earliest illustration of this vessel.

Our illustration, which is probably the first representation of the Merrimac ever published, was drawn from the description of a mechanic who had just come from the South, where he had assisted in the reconstruction of the ship. It was published before she was at her load line, which will account for the fact that she is shown with a much higher freeboard than she actually possessed.

The answer of the North to the challenge of the South was made in the launch of the turret ship Monitor, Ericsson's famous creation. In her design it was sought to produce a ship that should be invulnerable, of light draught for operation in the Southern harbors, carrying few guns, and that should be capable of rapid construction. The most novel and epoch-making feature was the placing of the guns within an armored revolving turret. This was not a new idea, but it was the first practical application and test of it. Others had already suggested it, but to the United States navy belongs the credit of the successful adoption of a design, which as far back as the Crimean war had been offered by Ericsson to the Emperor Napoleon, and rejected in favor of broadside plating.

The Monitor was built in 118 days. She was of 1000 tons displacement; 172 feet long, 41½ feet beam, and drew 10½ feet of water. Her deck was plated with 1 inch, and her sides, which overhung the hull proper, with 5 inches of iron, her freeboard being only 2 feet. The turret was 20 feet diameter, inside, by 9 feet high, and revolved, not, as is the practice now, upon peripheral rollers, but upon a central pivot within the ship's hull. It was protected by eight one inch iron plates, and the armament consisted of two 11 inch Dahlgren smooth bores. Forward of the turret was an iron pilot house 4 feet high covered with a 2 inch plate. The deck was pierced by two square smoke stacks and two blow holes. In the face of a storm of adverse criticism and prediction of disaster, the Monitor was completed and launched and dispatched to Southern waters. None too soon did she appear on the scene. The Merrimac was already at her work of destruction, and in one day, March 8, 1862, she had engaged three Northern ships of from thirty to fifty guns, in Hampton Roads, and administered a crushing defeat, receiving but little hurt herself. On the evening of the same day the Monitor steamed into the harbor, and on the day following was fought one of the most memorable duels of history. The story of the fight is too well known for repetition. It proved the superiority of armor to shot, the latter glancing from the former, and inflicting but little damage. The Monitor fired once every 7 minutes, the Merrimac once every 15 minutes. The superior turning power of the Monitor and the wide arc of fire through which she could use her guns proved a great advantage. The failure of either ship to inflict serious injury upon the other, however, was due largely to the fact that the Monitor was using light charges, lighter than was necessary, in her 11 inch guns, and the Merrimac was without solid shot.

The effect of the Monitor and her successors upon naval construction was far reaching, and showed itself in the general adoption of the turret by the navies of the world. It may without exaggeration be said that this little vessel was the father of the modern battleship, whether it be a Massachusetts, a Majestic, or a Charlemagne.

Equally valuable were the lessons of the war in relation to all matters of sea coast and river defense. One of the first encounters took place at New Orleans, when Farragut forced his way past the forts and through a strong boom and captured the city. It was a bold stroke on the part of the Northern admiral, for it was considered in those days that stone forts such as those below New Orleans were sufficient to bar the passage of a stronger fleet than that possessed by Farragut. The forts, however, were indifferently armed with old pattern 8 and 10 inch guns, and would undoubtedly have rendered a better account of themselves if better armed and manned. There were 17 ships in the fleet, mounting in all 192 guns. The same feat was repeated two years later at Mobile, when the fleet forced its way through a line of torpedo defenses under the concentrated fire of Fort Morgan. On both occasions the value of extemporized side armor was proved, and in these early days of the contest between gun and armor, the advantage lay with the armor. On the other hand, the early actions off Charleston, and particularly against Fort Sumter, were a triumph for the forts. On this occasion the fleet under Dupont, the Northern commander, consisted of nine ironclads, mounting in all seven 15 inch, twenty-two 11 inch and two 50 pounder smooth bores, with three 150 pounder rifled guns. The forts mounted ten 10 inch, nineteen 8 inch, and eighteen 32 pounder smooth bores, with ten 10 inch mortars, two 8 inch, seven 42 pounder and eight 32 pounder rifled guns, or 74 guns in all. The ironclad fleet concentrated its fire upon Fort Sumter, and bombarded it for an hour, but "the 15 inch shells which were to have blown in the masonry of Fort Sumter did nothing of the kind." One 10 inch gun was temporarily disabled,

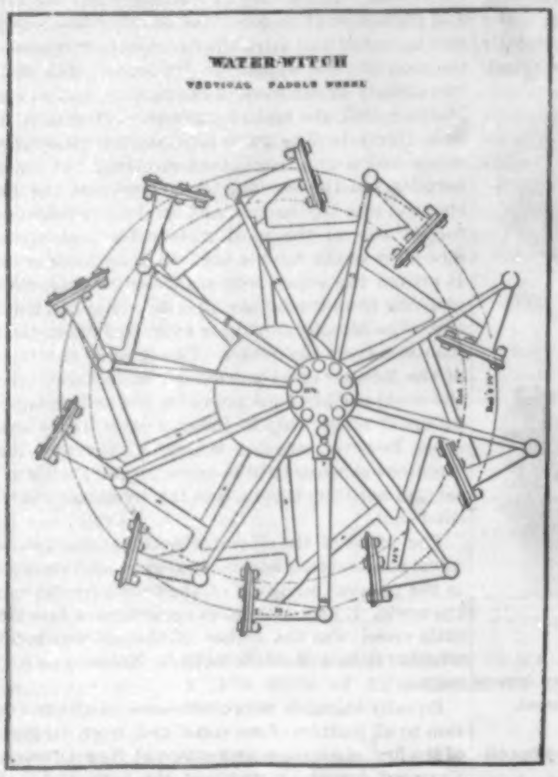
THE FEDERAL IRONCLAD MONITOR, 1861.

Displacement, 1,000 tons; length, 172 feet; breadth, 41½ feet; draught, 10½ feet; armor on turret, 8 inches thick; armament, two 11 inch smooth bores.

one 8 inch gun burst, seven men were wounded and one killed. In the fleet the Keokuk was sunk, and the other ships were hit from thirty-five to sixty times, with temporary disablement of guns and turrets, though the damage was on the whole slight, considering the hail of heavy projectiles. The failure of this attack seems to show that the coast defense fortifications of those days were proof against the attack of battleships, though a later attack on Sumter with Parrott rifles, it is true, was more destructive. It is certain that the developments in artillery since the war are favorable to the modern fort, inasmuch as the enormous weight of the heaviest modern guns limits their use on the ship, but offers no objection to their emplacement within land fortifications.

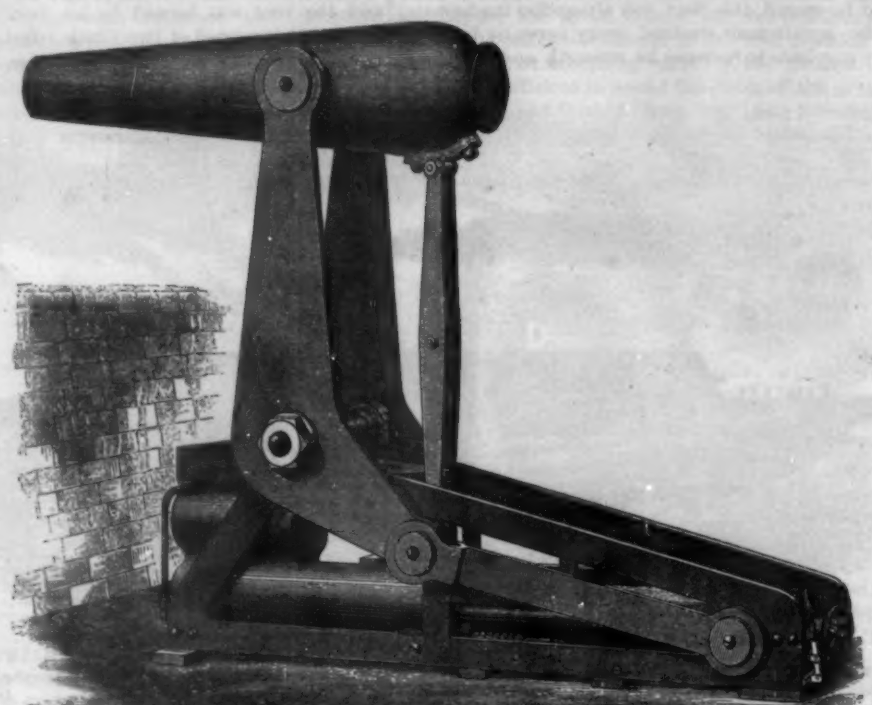
Before passing on to the present decade mention must be made of the destructive work of the Confederate cruisers. The story of the ravages of the Alabama and her final sinking by the Kearsarge is well known; and it is largely to the striking success of this ship that the large percentage of swift, lightly armed cruisers in modern navies is due. The Alabama and her mates practically swept the American merchant marine from the high seas, and had it not been for its fleet of swift blockade runners, the South would have collapsed many months before the final capitulation actually took place.

At the close of the war silence fell upon the busy dockyards of the navy—a silence which was to be practically unbroken for the next twenty years. All the accumulated experience of the past four years, and the ships of the new navy in which it was embodied, were laid open as a kind of reference library or school of instruction for the world at large. Foreign naval constructors were not slow to learn therein; and the student of naval progress must cross the water if he would follow the development of ships, guns, and armor during the next two decades. As the British navy stands at the front during this interim, both in constructional developments and numerical strength, it will be sufficient to show the advance approximately by quoting the details of particular ships of this navy. (See table below.)



VERTICAL OR "FEATHERING" PADDLE WHEELS OF THE WATER WITCH THE SECOND.

First of this type to be used in the navy, 1853.



PNEUMATIC DISAPPEARING GUN CARRIAGE FOR COAST DEFENSE.

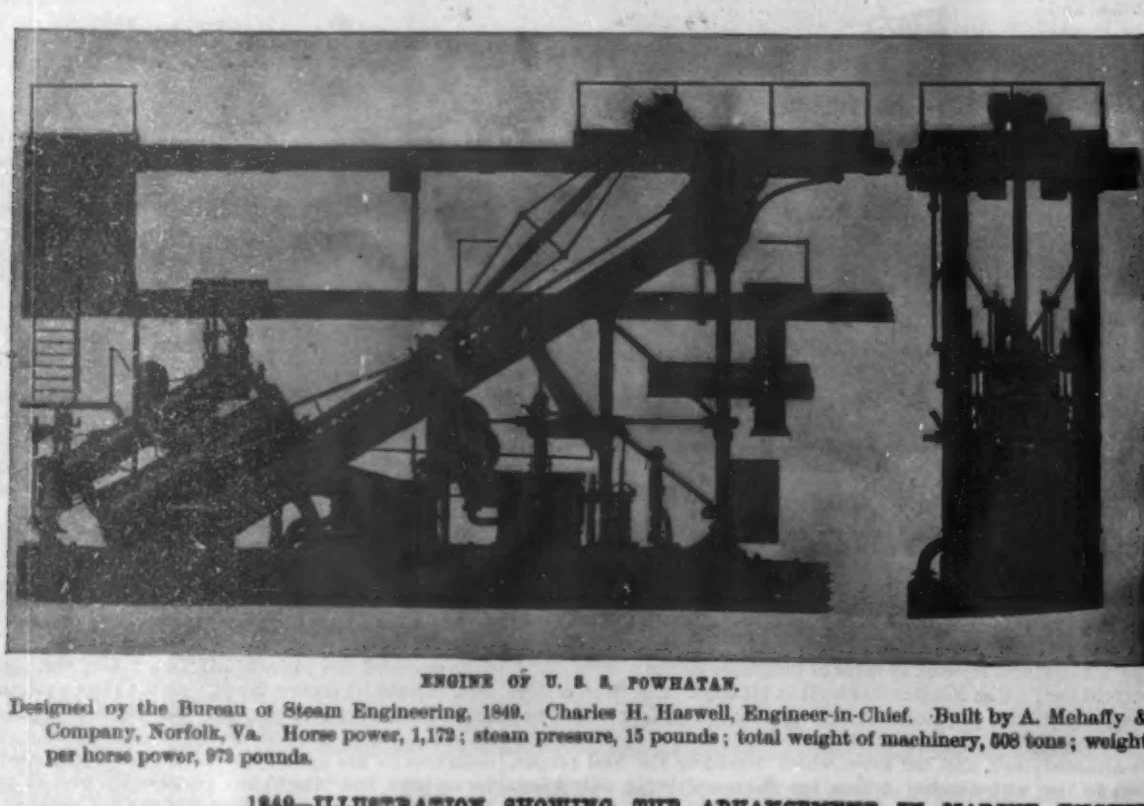
Invented by Captain James B. Eads in 1872.

Ship.	Date of design.	Displacement.	Speed in knots.	Armor in inches.	Guns.	Stages of development.
Devastation..	1870	9,330	14	12 in. to 14 in. iron.	12 inch 35 ton muzzle loading.	Great increase in size of ships, guns and thickness of armor.
Inflexible....	1876	11,880	12·8	16 in. to 24 in. steel and iron compound armor.	16 inch 80 ton muzzle loading.	Use of steel for armor. Continued increase in size of ships, guns, and armor.
Camperdown.	1880	10,600	16·9	18 in. compound.	13½ in. 67 ton breech loading. 6 in. B. L. secondary battery.	Use of steel for hull. Twin screws. Breech loading guns mounted in lofty barbettes. Strong secondary battery.
Imperieuse...	1881	8,400	16·75	10 in. compound.	9·2 in. and 6 in. breech loading.	Belted cruiser type.
Medea.......	1885	2,800	19	1½ in. protective deck.	6 in. guns B. L.	High speed protected cruiser type.

The interval from 1865 to 1885 had also seen the launching of the Esmeralda, the first of the modern cruiser type, and the development of the automobile torpedo and the torpedo boat, with a host of minor but important devices for increasing the destructiveness of naval warfare.

Toward the close of this period the United States awoke to the fact that, in the modern sense of the term, they were practically without a navy, and Congress made a modest start in the construction of one by authorizing, in 1883, the building of three protected cruisers, the Atlanta and Boston, single screw ships, of 3,000 tons displacement and 15·6 knots speed, and the Chicago, of 4,500 tons and 15·1 knots; the armament consisting of 6 and 8 inch breech-loading rifled guns. The work of creating a modern navy has gone forward steadily ever since, and the story of its growth and success is epitomized in the table on the next page.

Bearing in mind how thoroughly up to date are the various war ships in this tabulation, it is a most creditable showing, and in many respects the new navy is unique among the navies of the world. Compared with the ships of other nations, upon a basis of displacement,



ENGINE OF U. S. S. POWHATAN.

Designed by the Bureau of Steam Engineering, 1849. Charles H. Haswell, Engineer-in-Chief. Built by A. Mehaffy & Company, Norfolk, Va. Horse power, 1,172; steam pressure, 15 pounds; total weight of machinery, 508 tons; weight per horse power, 973 pounds.

ENGINE OF U. S. TORPEDO BOAT No. 2.

Designed by the Bureau of Steam Engineering, 1891. George W. Melville, Engineer-in-Chief. Built by Iowa Iron Works, Dubuque, Iowa. Horse power, 1,800; steam pressure, 250 pounds; total weight of machinery, 45 tons; weight per horse power, 56 pounds.

1849—ILLUSTRATION SHOWING THE ADVANCEMENT IN MARINE ENGINEERING—1891.

(The two engines are drawn to the same scale, so that the drawings show the relative sizes.)

THE NEW UNITED STATES NAVY.

Name.	Authorized.	Type of Ship.	Displacement.	Speed.	Armor.	Main Armament.
Atlanta, Boston,	1883	Protected cruiser.	3,000	15·6	1½ in. deck.	2 8-in. B. L. rifles. 6 6 " "
Chicago	1883	" "	4,500	15·1	1½ " "	4 8 " " 8 6 " " 2 5 " "
Dolphin	1883	Dispatch boat.	1,486	15·5	....	2 4 " R. fire "
Charleston	1885	Protected cruiser.	3,730	18·20	2 " to 3 in. deck.	2 8 " B. L. " 6 6 " "
Newark	1885	" "	4,098	19·00	2 " " 3 " "	12 6 " " "
Petrel	1885	Gunboat.	892	11·8	3/8 " " 3/8 " "	4 6 " " "
Yorktown	1885	"	1,710	16·14	3/8 " deck.	6 6 " " "
Maine	1886	Turret battleship.	6,682	17·45	8 " to 12 in.	4 10 " " " 6 6 " " "
Texas	1886	" "	6,315	17·00	12 "	2 12 " " " 6 6 " " "
Baltimore	1886	Protected cruiser.	4,413	20·09	2½ " to 4 in. deck.	4 8 " " " 6 6 " " "
Vesuvius	1886	Dynamite "	929	21·42	3/16 " deck.	3 15 " dynamite guns.
Cushing	1886	Torpedo boat.	105	22·5	.....	3 1-pounder R. F. 3 18-in. torpedoes.
Monterey	1887	Monitor.	4,084	13·6	7½ " to 13 in.	2 12 " B. L. rifles. 2 10 " " "
Philadelphia	1887	Protected cruiser.	4,324	19·68	2½ " " 4 " "	12 6 " " "
San Francisco	1887	" "	4,098	19·53	2 " " 3 " "	12 6 " " "
Bennington	1887	Gunboat.	1,710	17·5	3/8 " deck.	6 6 " " "
Concord	1887	"	1,710	16·8	3/8 " "	6 6 " " "
New York	1888	Armored cruiser.	8,200	21·00	3 " to 6 in. deck. 4 " " 10 "	6 8 " " " 12 4 " R. F. "
Olympia	1888	Protected "	5,870	21·78	2 " " 4¾ " "	4 8 " B. L. " 10 5 " R. F. "
Cincinnati	1888	" "	3,213	19·00	1 " " 2½ " "	1 6 " " rifle. 10 5 " " rifles.
Detroit	1888	Cruiser.	2,089	18·71	5/16 " " 7/16 " "	9 5 " " "
Marblehead	1888	"	2,089	18·44	5/16 " " 7/16 " "	9 5 " " "
Montgomery	1888	"	2,089	19·05	5/16 " " 7/16 " "	9 5 " " "
Raleigh	1888	Protected cruiser.	3,213	19·00	1 " " 2½ " "	1 6 " " " 10 5 " " "
Bancroft	1888	Training ship.	839	14·37	¼ " " 5/16 " "	4 4 " R. F. "
Katahdin	1889	Harbor defense ram.	2,155	16·25	3 " " 6 " "	4 6-pounder R. F.
Castine	1889	Gunboat.	1,177	16·03	5/16 " " 3/8 " "	8 4-in. R. F.
Machias	1889	Gunboat.	1,177	15·5	5/16 " " 3/8 " "	8 4 " "
Indiana	1890	Coastline battleship.	10,288	15·55	6 " " 18 "	4 13-in. B. L. rifles. 8 8 " " " 4 6 " " "
Massachusetts	1890	" "	"	16·15	do.	do.
Oregon	1890	" "	"	16·78	do.	do.
Columbia	1890	Protected cruiser.	7,375	22·8	2½ " " 4 " "	1 8 " B. L. rifle. 2 6 " R. F. rifles. 8 4 " " "
Ericsson	1890	Torpedo boat.	120	24·00	....	3 1-pdr. " "
Minneapolis	1891	Protected cruiser.	7,375	23·07	2½ " " 4 " "	1 8-in. B. L. rifle. 2 6 " R. F. rifles. 8 4 " " "
Iowa	1892	Seagoing battleship.	11,410	16·00	6 " " 15 "	4 12 " B. L. " 8 8 " " " 6 4 " R. F. "
Brooklyn	1892	Armored cruiser.	9,271	21·07	3 " " 6 " " 4 " " 8 "	8 8 " B. L. " 12 5 " R. F. "
Three Helena type.	1893	Gunboats.	1,392	13·00	5/16 " " 3/8 " "	8 4 " " "
Submarine boat	1893	Torpedo boat.	168	8·00	....	2 torpedo tubes.
Nos. 3, 4 and 5	1894	" "	142	24·5	....	3 1-pdr. R. F. guns. 3 18 in. Whiteheads.
Kearsarge	1895	Seagoing battleship.	11,525	16·00	9 " " 17 "	4 13 " B. L. rifles. 4 8 " " " 14 5 " R. F. guns.
Kentucky	1895	" "	11,525	16·00	do.	do.
Six gunboats	1895	Gunboats.	1,000	12·00	....	6 4 " " "
Nos. 6, 7 and 8	1895	Torpedo boats.	190	27·5	....	3 18 " Whiteheads. 4 1-pdr. R. F. guns.
Three battleships	1896	Battleships.	12,000	16·00	Similar to Kearsarge.	....
Nos. 9, 10 and 11	1896	First-class torpedo boats.	......	30·00	......	....
Nos. 12—18	1896	Second class torpedo boats.	.....	26·00	....	....

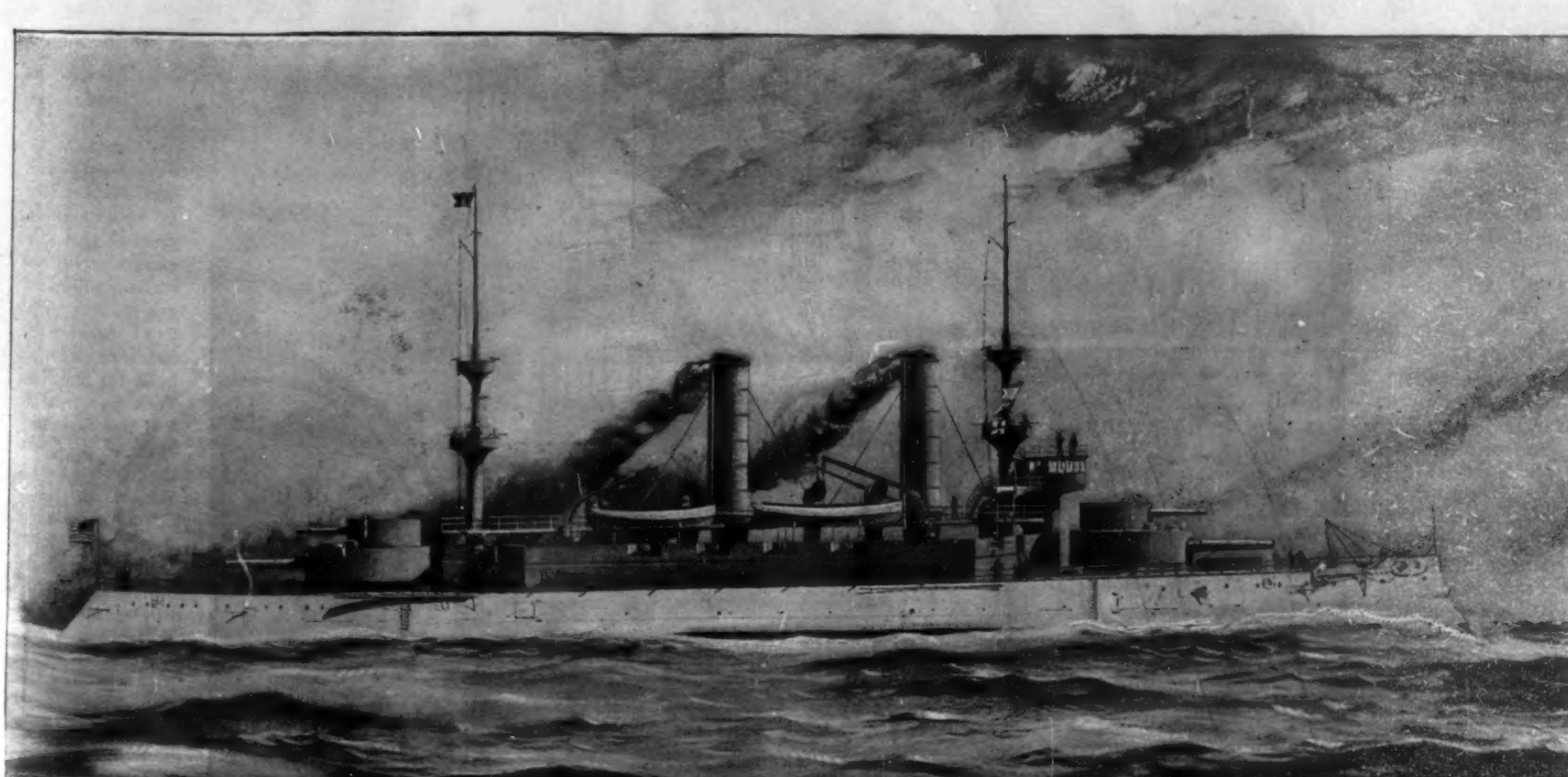
Note 1. To this list must be added the four completed monitors of the Miantonomoh type, and the Puritan.
Note 2. Where not specified as deck armor the dimensions relate to side and turret armor.

they are certainly in many respects greatly superior. That is to say, size for size, they are faster, more heavily armed and armored, and better protected. The Massachusetts, as a battleship; the Brooklyn, as an armored cruiser; and the Minneapolis, as a protected cruiser, are relatively unmatched by anything afloat to-day. The following table shows the increase in fighting power of the individual ship in the past fifty years:

	Date.	Displacement, Tons.	Speed knots	Armor.	Weight of broadside.	Maximum penetration through iron.
Mississippi.	1846	3,220	7·33	none	324 lb.	8 in. at 500 yds.
Massachusetts	1896	10,288	16·15	18 in. steel.	5,724 lb.	30 in. at 500 yds.

Equally remarkable has been the improvement in engines and boilers; indeed, it may safely be said that the development of the marine engine, both in the merchant marine and in the navy, has been the most potent factor in bringing the steam engine up to its present high standard of efficiency. The necessity of keeping down the size of war ships, coupled with the high speed required, and the all too scanty space allotted to engines and boilers, have led the marine engineer to bend every energy to the reduction of weight, and the increase of efficiency. What was merely desirable on land was absolutely imperative on the seas, and hence the marine engine has usually led the way in the improvement of steam machinery. The compound engine, with its higher pressures and wider range of expansion; the triple and then quadruple expansion engine—a further advance upon the same line; the larger use of steel in construction of engines and boilers; the extended use of water tube boilers; forced draught; and many other advanced forms of steam engine practice, were early utilized and improved by the naval engineer. The accompanying illustration of the engines of the Powhatan, 1849, and the Ericsson, 1891, for which we are indebted to the present Engineer-in-Chief of the Navy, George W. Melville, shows very graphically the decrease in bulk and the increase in power of the marine engine. While steam pressure has increased from 15 to 250 pounds, and the revolutions per minute from 14 in the paddle steamer to 412 in the screw steamer, the weight of machinery per horse power has decreased from 972 to 56 pounds!

The development of guns and armor during the past half century has fully kept pace with the advance in ships and engines. In 1846 the guns were cast iron smooth bores, firing spherical projectiles at low velocities; and for armor the ships relied upon great thickness of wood. The cast iron Columbiads ranged in size from the 8 inch, 4¼ ton gun, to the 20 inch, 57½ ton gun, the former throwing a 68 pound, the latter a 1,000 pound projectile. The year 1860 saw the commencement of the manufacture of the celebrated Parrott gun, which was destined to play such an important part in the war. In this gun were introduced the two elements of reinforcement and rifling, the body of the gun being of cast iron, with a wrought iron hoop shrunk on over the breech. They were very formidable weapons, an 8 inch rifle having, in 1865, thrown a 52½ pound shell, with an initial velocity of 1,809 feet per second, thereby establishing a claim for the Parrott as "the most formidable service gun extant" at that time. After the war there was twenty years of stagnation, similar to that in the navy, in the matter of ordnance and coast defense, and in 1885, the brick and stone forts of 1860–65, surmounted by antiquated smooth bores and Parrott rifles, were all the defense which the nation could offer in the event of attack by the powerful artillery of a foreign power. In that year a complete investigation of the defenseless condition of our various seacoast cities was made by what is known as the Endicott Board, who reported that to put the coastline in a state of thorough defense would require the expenditure of about $100,000,000 for guns and forts. The recommendations of this board, modified to

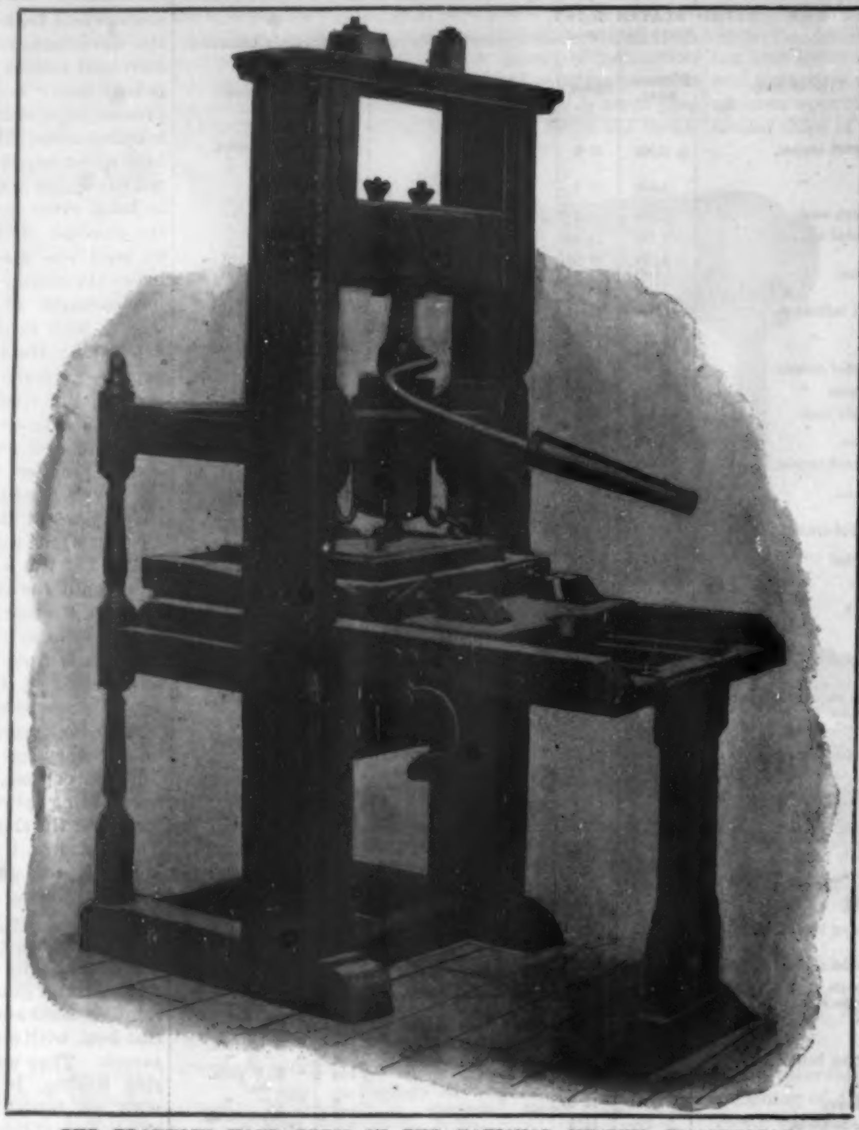


THE KEARSARGE, 1896; SEA-GOING BATTLESHIP.

Displacement, 11,525 tons; speed (proposed), 16 knots; material of construction, steel; type, superimposed turret and rapid-fire broadside; armor, 9 inches to 17 inches, Harvey steel; armament, four 13 inch and four 8 inch breech-loading rifles; fourteen 5 inch rapid-fire guns; thirty smaller rapid-fire guns; five torpedo tubes.

meet the present requirements, would call for the mounting of about 1,500 modern guns and mortars of from 8 inch to 16 inch caliber, and 360 rapid fire guns. At the present writing New York, San Francisco and Boston have between them some 50 to 60 modern guns and mortars mounted in place; and including the sum voted at the close of the Congress of 1895-96, about 20 per cent of the necessary sum has been appropriated. The accompanying diagram of a modern United States 8 inch rifle may be taken as typical of the guns which will be mounted in the proposed system of coast defense. It is an all-steel, built-up hooped gun, with a breech-loading mechanism of special pattern, and great facility of manipulation. This comparative diagram, together with the comparative table of the 8 inch guns of the Mississippi and the Massachusetts, show the growth in size and power during fifty years. It is only during the past few years that the manufacture of modern armor has been undertaken in the United States, yet we have easily moved to the front place by the introduction of the Harvey system of face-hardened armor, by means of which the resisting power of a plate is increased some 50 per cent. Already our makers are filling important orders for European navies, and the English Admiralty have adopted a modified form of the system in preference to any other for all ships now building and planned.

FIFTY YEARS IN THE PRINTING BUSINESS.

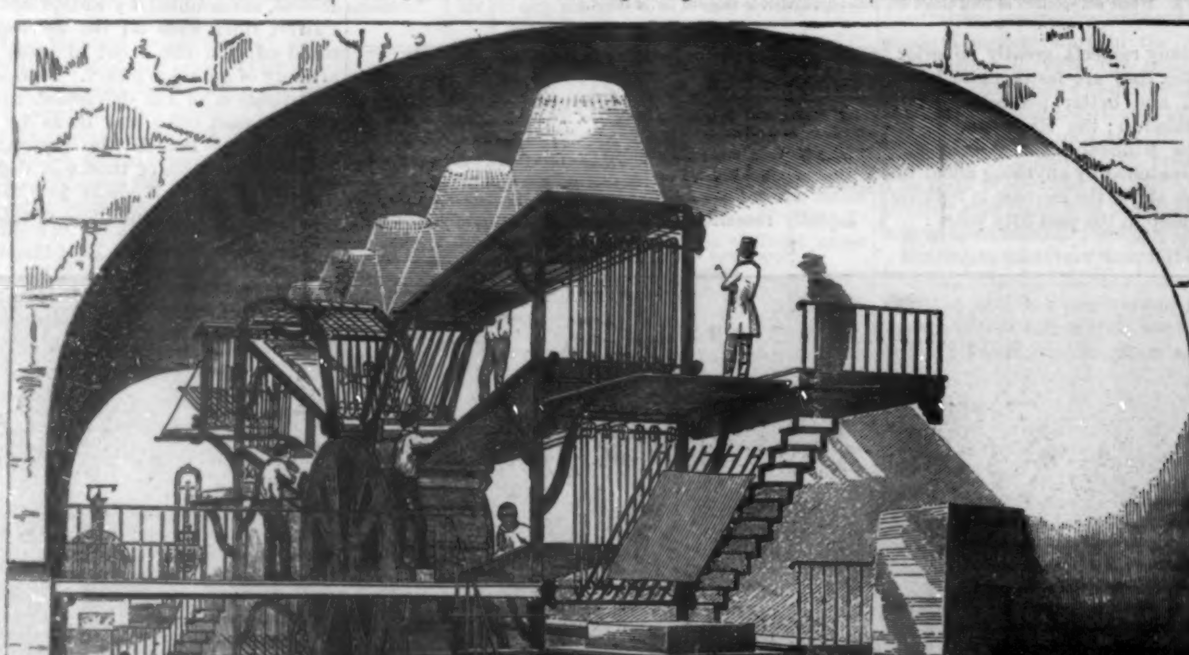


THE FRANKLIN HAND PRESS IN THE NATIONAL MUSEUM WASHINGTON.

The far more general dissemination of intelligence, the rapid and efficient means of intercommunication between all parts of the world, with the cheapening and broadening of all educational facilities, constitute, perhaps, the most notable feature of the progress of the world during the past half century, and the one most vitally contributing to the success of all our great industries—the perfection and introduction of most of the world's great inventions. The printing press has been the great disseminator of knowledge, the cheap educator of the people. As a promoter of its efficiency the electric telegraph has performed most splendid service, finding therein its earliest efficient support, and an array of inventors have found a profitable field in the numerous devices which contribute to the perfection of the printing press of to-day or add to its ability to most promptly and cheaply serve the largest number of readers. In the development of the printing art in the United States the name of Franklin will ever be memorable, so that it is most fitting that we should illustrate Franklin's own press before reviewing the great inventions which contributed so largely to the dissemination of cheap literature and which more properly belong to the epoch we are considering.

The press shown in the engraving is what is known as a Ramage press, and it was used by Benjamin Franklin in London in 1725. The press is constructed almost entirely out of wood, though iron was subsequently used in many of the parts. On the clumsy frame the great statesman has left the marks of his inky fingers. It is now in the National Museum, at Washington. In the early part of the present century Earl Stanhope invented a press made entirely of iron, the frame being cast in a single piece. The power was applied by a combination toggle joint and lever. The Columbian press was invented by a Philadelphian in 1817. The power was applied by a compound lever. In 1829 the Washington press of Samuel Rust was introduced, and many improvements were introduced in inking, and later a self-inking device was invented. The first power press produced in America was that of Daniel Treadwell, of Boston, in 1822. The Adams press was invented in 1830, and has superseded all other platen presses, the impression being given by raising the bed upon which the form rests against a stationary platen. The first attempt to make a rotary press was that of Friedrich König, in 1814. In this the type moved horizontally, and it could give 1,800 impressions per hour.

The first great step toward facilitating the rapid and cheap production of the modern newspaper was made by Col. Robert Hoe, of New York, about 1840, when the first of the type-revolving presses was built. At about the same time a type-revolving press on materially different lines, the Applegath machine, was brought into practical use in England. This machine was first employed by the London Times in 1848. In the Applegath machine the typeholding cylinder revolved on vertical axes, and the machine could print about 12,000 single sheets on one side in an hour. In the Hoe machine the type cylinder revolved on a horizontal axis. This arrangement for feeding the sheets was more simple, and the capacity of the press varied according to the number of impression cylinders arranged around the type cylinder, these presses being successively made with four, six, eight, and ten impression cylinders, respectively. A four-cylinder press of this kind was built for the Philadelphia Ledger in 1845. The first eight-cylinder press was built for the New York Sun in 1850, and the first ten-cylinder press for the New York Herald in 1857. Our engraving shows the eight-cylinder Hoe press of 1850 as furnished to the New York Sun office. The average capacity of the presses was 2,000 single sheets per hour per cylinder, or 20,000 sheets per hour, on one side, on the largest press, the ten-cylinder. These presses were 37 feet long, 18 feet high, and 21 feet wide, and were



EIGHT CYLINDER HOE PRESS OF 1850 USED IN PRINTING THE NEW YORK SUN

Capacity, 20,000 per hour. Reproduced from an early print in the SCIENTIFIC AMERICAN.

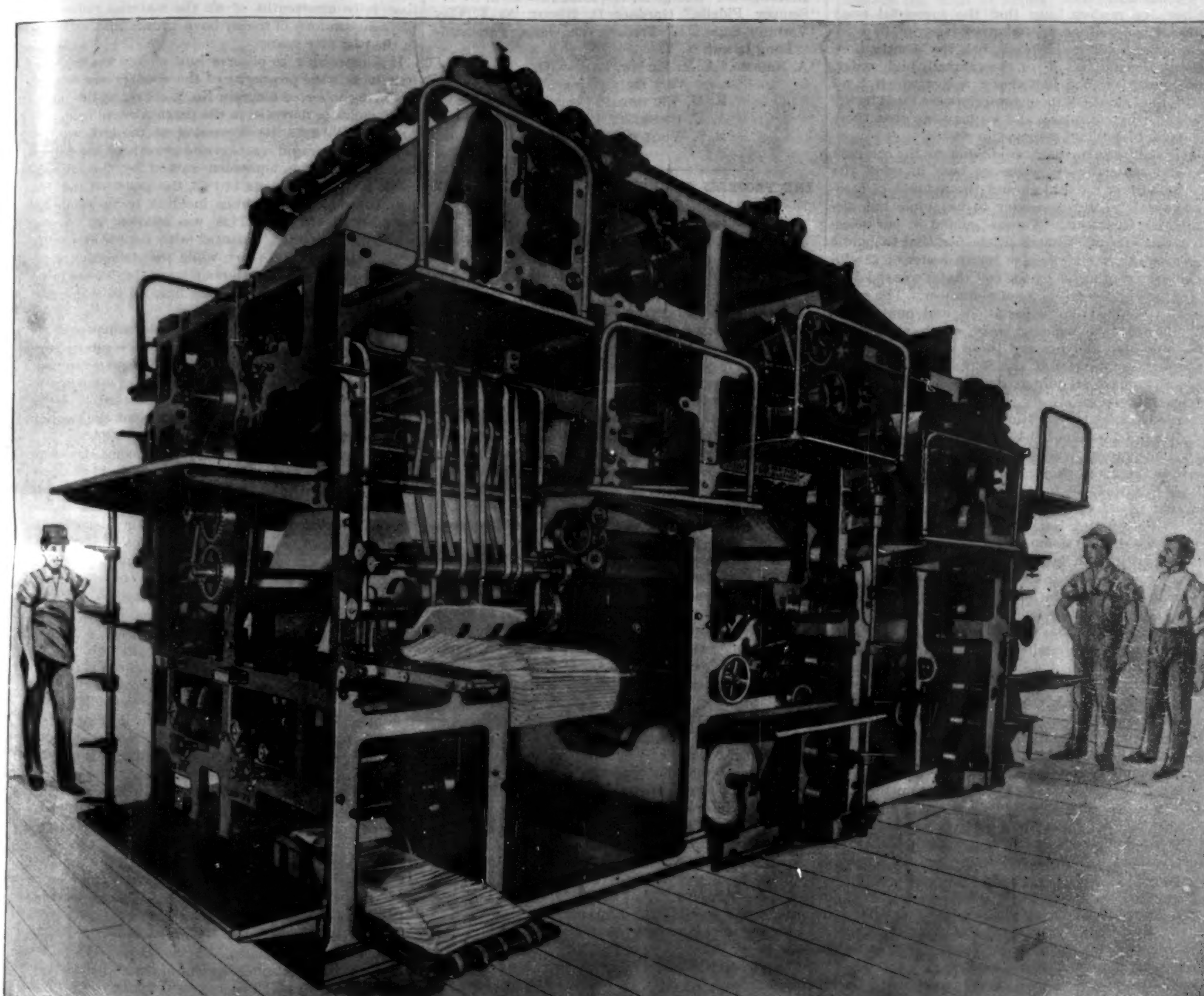
beautiful pieces of mechanism to look at in full operation, as all their working parts could be seen to advantage, the ten feeders, five on each side, supplying the sheets, which traveled on tapes to and around an impression cylinder, the latter pressing the paper against the inked type, which was held on the large central revolving cylinder. Between each two impression cylinders the type passed under inking rollers, and the paper printed upon was passed back by tapes to delivery boards, each revolution of the main cylinder of the ten-cylinder press thus printing ten separate sheets of paper.

The great advance thus effected upon all previous means of fast newspaper printing was deemed one of the highest triumphs of mechanical genius during the decade from 1850 to 1860, but this success was entirely along the lines established by the presses at work in 1845. Still faster work was, however, imperatively demanded, to meet the enormous increase in the public demand for newspapers, which publishers were enabled more easily to furnish at reduced prices, when the substitution of wood pulp for rags had greatly lessened the cost of paper. But it is of primary importance to note, in connection with the next great advance in fast printing, that all promptly issued editions of newspapers, prior to 1860, were printed from the type forms direct. To make stereotype plates with sufficient expedition for the requirements of newspaper work had not, before that time, been considered practicable, but this difficulty was removed in 1861 by the employment of a steam bed to dry a novel style of papier mache matrix, or mould, which could be conveniently used for making stereotype reproductions of the type pages, in the form of plates to fit around cylinders. At first it required half an hour to make a single plate, but now a plate is made in about seven minutes, and half a dozen duplicates of the same plate can be made in fifteen minutes. This made possible the modern "perfecting" press, so called because both sides of the paper are printed in passing through the press. In its largest size, the octuple machine, of which but one has yet been placed in operation, this press prints, folds, and counts 96,000 complete eight-page papers per hour, or 48,000 sixteen-page papers, the size of the page being that of the ordinary daily newspaper. The press has eight plate or impression cylinders, there being eight stereotype plates or pages on each cylinder, and the paper of double width is fed from four independent rolls, 73 inches wide, one side being printed upon as the paper passes over the set of stereotype pages on one cylinder and the other side being printed upon as it passes over the plates of another cylinder. The paper rushes through the cylinders at a speed of thirty-two and one-half miles an hour, the several sheets being separated and folded, and passed out of the press with accuracy and precision. The entire work is automatically performed, after the press is once started, but it requires the active labor of ten men and boys to operate it and to remove the folded sheets as fast as they are printed.

We illustrate one of these presses, which is now in operation in the printing room of the New York World. The two others will also be placed in position as soon as completed. The presses are 14 feet high and 25 feet long. The machine delivers the papers counted out in bundles of twenty-five. When all three presses are installed, they will be able to print each hour 748,000 eight-page sheets, or an equivalent of an output of over 42 tons of printed matter per hour.

Besides, however, the improvements which have been made to facilitate the printing of the daily newspaper, there has been equally marked progress during the past fifty years in bettering the appliances for the printing of books, magazines, and illustrated newspapers. In 1837, Messrs. Harper & Brother, the great New York publishers, had in use thirty-seven hand presses and but one machine press, and between 1840 and 1855 two kinds of presses had almost the exclusive sale in the American market, the Adams and the Hoe. The Adams press was, until a much later period, considered the most excellent of all presses for book work. It had a flat bed and platen, the impression was even and the distribution of the ink most perfect, but its speed was only about 1,000 impressions an hour. There are now less than ten manufacturers of printing presses in the United States, making the presses commonly used in book and job printing offices, and for newspapers having but a limited circulation. In these presses the type forms are placed on a flat bed which reciprocates under a cylinder around which the paper is carried to receive its impression, this style of press allowing for the most even inking of the forms as they pass under horizontally arranged rollers. Among presses of this description which were early in the field, and have attained a wide use, have been, besides the presses made by R. Hoe & Company, the A. B. Taylor, the Campbell, the Cottrell, the Potter and the Babcock. An objection to the use of these presses for book work was at first found in the fact that the stereotype plates were liable to be broken by the great pressure brought to bear upon them by the impression cylinder, but this objection was overcome by the introduction, about 1850, of electrotyping, whereby much better and stronger plates could be made.

In noting the great size of the newspaper of the present day, the large amount of reading matter daily presented, one other agency has also had a most important influence, namely, the typesetting machine. It is probable that in no other line of effort have so many inventors labored as in that of making an efficient typesetting machine, and so far has success been attained that in most of the large newspaper offices of the country typesetting machines are now employed. Among such machines may be mentioned the Alden, the Thorne, the Paige, the McMillan, the Rogers, and the Mergenthaler. The latter sets and casts type lines, and was fully illustrated and described in the SCIENTIFIC AMERICAN of January 13, 1894.



THE HOE OCTUPLE PRESS OF THE NEW YORK WORLD.

Capacity, 96,000 per hour, or 1,600 every minute. The paper travels through the press at the rate of 32½ miles an hour. The paper is printed, pasted, cut, folded, and counted automatically.

Scientific American.

MUNN & CO., Editors and Proprietors.

PUBLISHED WEEKLY AT

No. 361 BROADWAY, NEW YORK.

THE PRIZE ESSAY OF OUR SEMI-CENTENNIAL ANNIVERSARY NUMBER.

We take much pleasure in announcing that the winning essay in our prize competition on the subject of the progress of invention during the past fifty years was written by Mr. Edward W. Byrn, of Washington, D. C.

The names of the writers of the five next best essays, to be published in subsequent issues of the SCIENTIFIC AMERICAN SUPPLEMENT, are as follows: Edmund Becker, Washington, D. C.; George M. Hopkins, Brooklyn, N. Y.; Gardner D. Hiscox, New York City; Frederic de Garis, Patchogue, Long Island, and A. M. Farlow, Barlow, Ohio.

When our readers learn that the successful essay was closely pressed for first place by many of its competitors, they will understand that the competition, taken as a whole, was of an exceptionally high order. As compared with the half dozen essays which head the list, the balance of the manuscripts are rated by the judges at a high standard, and we may say that there are few that lapse into mere mediocrity.

This result is particularly creditable to the competitors, and especially so, when we bear in mind the great breadth of the subject and the amount of careful research that was necessary to its ample but discriminating treatment. We were guided in our selection of this subject as much by the fact that to handle it successfully would involve many hours of careful preliminary reading, as by the fact that it was specially appropriate to a semi-centennial number. The result has fully justified our expectations, and our readers will find that the winning essay, which we publish in the adjoining columns, and those which will follow in consecutive numbers of the SCIENTIFIC AMERICAN SUPPLEMENT, bear the internal evidence of careful and systematic research.

The presence of college students among the competitors calls for mention of the fact that the proximity of the summer examinations has shut out many college men from this competition; and the efforts of those who did send in their essays call for a word of special recognition.

It is an interesting fact, worthy of record here, that the interest in the competition was not confined to America, but that it brought some excellent MSS. to this office from different quarters of the globe. Any further discussion of the merits of the essays can best be given in the words of Judge A. P. Greeley, of the Patent Office, Washington, who, in forwarding his report, says: "Many of those which I have placed somewhat low on the list are of decided merit, and only fall of higher rating because of failure to cover the broad field of invention. Some of them show a remarkably full and accurate knowledge on particular lines, without the broad grasp of the whole field.

"I have been much interested in these essays. They evidence a widespread knowledge and appreciation of the progress that has been made in the last fifty years. It has been by no means easy to determine the best one of the half dozen or more at the top of the list; but the selection I have made is the result of careful consideration, and is my best judgment in the matter."

The result of the vote on the question as to what invention introduced during the past fifty years has conferred the greatest benefit upon mankind places Bessemer Steel in the place of honor. Then come the Telephone and the Telegraph—though we think the relative order of these two should more justly be inverted. Following these come the Sewing Machine, the Reaper, the Electric Light, the Electric Motor, the Bicycle, the Grain Binder and the Westinghouse Air Brake. There were several miscellaneous votes, which we cannot give in detail; but our readers will pardon our mentioning with all modesty that not a few correspondents wrote that the SCIENTIFIC AMERICAN has conferred the greatest benefit upon mankind. While we cannot agree with this opinion, we appreciate highly the kind feeling which prompts the sentiment.

In the course of the past fifty years expressions of good will like this have been by no means infrequent; and we enter upon the second half century of our journalistic life with the confidence that these cordial relations between ourselves and our subscribers will strengthen as the years go by.

Our cordial thanks are due to Judge A. P. Greeley, of the Patent Office, Washington; Prof. R. H. Thurston, of Cornell University; and Prof. R. S. Woodward, of Columbia University, for the valuable service they have rendered in acting as a jury in the above competition. It would be difficult to find three gentlemen whose time is more fully occupied; and that they should have taken in hand just now a matter involving so much careful attention places both ourselves and our readers under a debt of obligation which we take this opportunity to acknowledge.

$250 PRIZE ESSAY COMPETITION.

THE AWARD.

Editor SCIENTIFIC AMERICAN:

Dear Sir: Having completed our examination of the essays on the subject of "The Progress of Invention During the Past Fifty Years," we beg to announce that the essay receiving the highest average rating was written by "Beta," who, on opening the sealed envelope accompanying the manuscript, was found to be Mr. Edward W. Byrn, of Washington, D. C. To him, therefore, the prize of $250 should be awarded. The names and addresses of the five authors receiving the next highest average ratings are given in order below. It remains only to add that each member of the committee examined the essays independently, marking them on a scale of 100, and that the average of the three independent ratings was taken in each case for the final rating of an essay.

"Liberty," Edmund Becker, office of Lighthouse Board, Treasury Department, Washington, D. C.
"Investigator," George M. Hopkins, Brooklyn, N. Y.
"Semper Fidelis," Gardner D. Hiscox, N. Y. City.
"Verbum Sap. III," Frederic de Garis, Patchogue, Long Island, N. Y.
"A. Malcom," A. M. Farlow, Barlow, O.

Very truly yours,
R. H. THURSTON, Cornell University.
A. P. GREELEY, U. S. Patent Office.
R. S. WOODWARD, Columbia Univ.
Committee.

THE PROGRESS OF INVENTION DURING THE PAST FIFTY YEARS.

PRIZE ESSAY BY "BETA" (EDWARD W. BYRN, A.M.)

If the life of man be threescore years and ten, fifty years will about mark the span of ripe manhood's busy labor, and the sage of to-day, turning back the pages of memory, may, as the times pass in review, enjoy the rare privilege of personal observation of, direct contact with, and positive knowledge concerning the events of this prolific period. To him what a vista it must present; what a convergence of the perspective; for the past fifty years represents an epoch of invention and progress unique in the history of the world. It is something more than a merely normal growth or natural development. It has been a gigantic tidal wave of human ingenuity and resource, so stupendous in its magnitude, so complex in its diversity, so profound in its thought, so fruitful in its wealth, so beneficent in its results, that the mind is strained and embarrassed in its effort to expand to a full appreciation of it. Indeed, the period seems a grand climax of discovery, rather than an increment of growth. It has been a splendid, brilliant campaign of brains and energy, rising to the highest achievement amid the most fertile resources, and conducted by the strongest and best equipment of modern thought and modern strength.

The great works of the ancients are in the main mere monuments of the patient manual labor of myriads of workers, and can only rank with the buildings of the diatom and coral insect. Not so with modern achievement. This last half century has been peculiarly an age of ideas and conservation of energy, materialized in practical embodiment as labor-saving inventions, often the product of a single mind, and partaking of the sacred quality of creation.

The old word of creation is, that God breathed into the clay the breath of life. In the new world of invention mind has breathed into matter, and a new and expanding creation unfolds itself. The speculative philosophy of the past is but a too empty consolation for short-lived, busy man, and, seeing with the eye of science the possibilities of matter, he has touched it with the divine breath of thought and made a new world.

It is so easy to lose sight of the wonderful, when once familiar with it, that we usually fail to give the full measure of positive appreciation to the great things of this great age. They burst upon our vision at first like flashing meteors; we marvel at them for a little while, and then we accept them as facts, which soon become so commonplace and so fused into the common life as to be only noticed by their omission.

Perhaps, then, it will serve a better purpose to contrast the present conditions with those existing fifty years ago. Reverse the engine of progress, and let us run fifty years into the past, and practically we have taken from us the telegraph, the sewing machine, the bicycle, the reaper and vulcanized rubber goods. We see no telephone, no cable nor electric railways, no electric light, no photo-engraving, no photo-lithographing nor snapshot camera, no gas engine, no web perfecting printing press, no practical woodworking machinery nor great furniture stores, no passenger elevator, no asphalt pavement, no steam fire engine, no triple expansion steam engine, no Giffard injector, no celluloid, no barbed wire fence, no time lock for safes, no self-binding harvester, no oil nor gas wells, no ice machines nor cold storage. We lose the phonograph and graphophone, air engines, stem winding watches, cash registers and cash carriers, the great suspension bridges, iron frame buildings, monitors and heavy ironclads, revolvers, torpedoes, magazine guns and Gatling guns, linotype machines, all practical typewriters, all pasteurizing, knowledge of microbes or disease germs, and sanitary plumbing, water gas, soda water fountains, air brakes, coal tar dyes and medicines, nitro-glycerine, dynamite and guncotton, dynamo electric machines, aluminum ware, electric locomotives, Bessemer steel, with its wonderful developments, ocean cables, etc. The negative conditions of that period extend into such an appalling void that we stop short, shrinking from the thought of what it would mean to modern civilization to eliminate from its life these potent factors of its existence.

As the issue of patents in this country is based upon novelty, it will aid us in the effort to appreciate this great movement to note the increase of United States patents in the past fifty years. Beginning in 1846, and dividing the time into periods of five years, the increase is shown most graphically in the scaled diagram No. 1.

If the growth of United States patents and the progress of the last half century can be taken as fairly correlated, what an insignificant thing is the little attenuated triangle back of 1846 compared with the swelling curves of the later period! It is probably safe to say that fully nine-tenths of all the material riches and physical comforts of to-day have grown into existence in the past fifty years.

It is interesting to observe how closely the grant of patents and the prosperity of the country are related. Referring to scaled diagram No. 2, the zigzag line marks the increase or decrease in the patents issued from year to year. We note the depression of the civil war, followed by the rapid reaction and growth of reconstruction. Again, the depression caused by the financial panic of 1873, and again in 1876, the unsettled and dangerous condition of politics incident to the contested presidential election. This was followed by another wave of prosperity, indented with depressions in the presidential election years, while the stringency of the times from 1890 to 1894 shows a marked influence in the corresponding depression in the line, all of which indicates a most sympathetic relation.

Passing now to the chronological development of the period, Morse had just harnessed the most elusive steed of all Nature's forces, and put it in the permanent service of man; when nitro-glycerine, discovered by Sobrero, in 1846, for the first time lent its terrible emphasis, and seemed to bring an awakening of the dormant genius of man.

Within the first decade (1846-1856) came the sewing machine, Bain's chemical telegraph, the Suez Canal, the House printing telegraph, the McCormick reaper, the discovery of the planet Neptune, the Corliss engine, the collodion and dry plate processes in photography, the Ruhmkorff coil, the Bass time lock for safes, the electric fire alarm of Channing & Farmer, Gintle's duplex telegraph, the sleeping car of Woodruff, Wilson's four-motioned feed for the sewing machine, Ericsson's hot air engine, the Niagara suspension bridge, and the building of the Great Eastern.

The next decade (1856-1866) brought with it the Atlantic cable, the discovery of the aniline dyes by Perkin, the making of paper pulp from wood, the discovery of coal oil in the United States, the invention of the circular knitting machine, the Giffard injector, for supplying feed water to steam boilers; the discovery of caesium, rubidium, indium and thallium; the McKay shoe sewing machine, Ericsson's ironclad monitor, Nobel's explosive gelatine, the Whitehead torpedo, and the first embodiment of the fundamental principles of the dynamo electric generator by Hjorth, of Denmark.

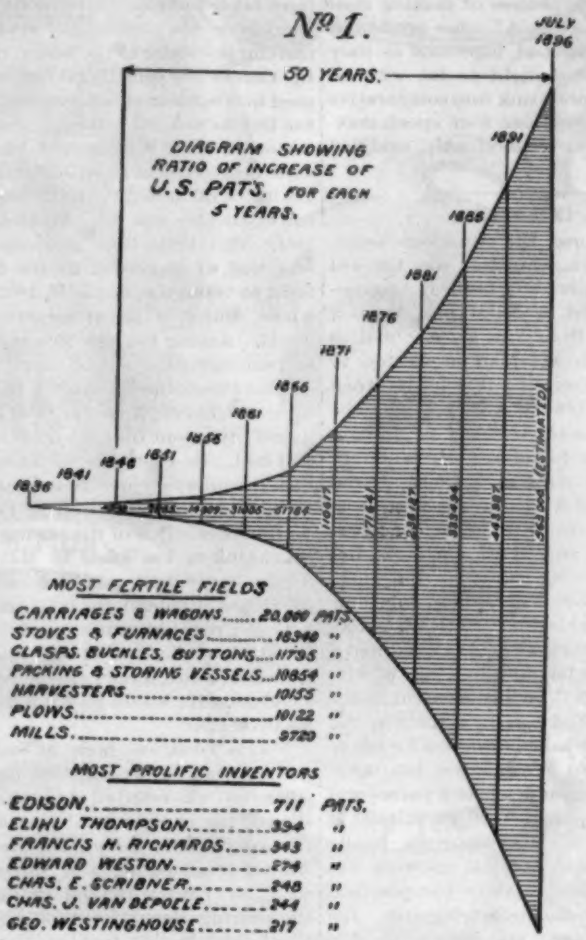
The next decade (1866-1876) marks the beginning of the most remarkable period of activity and development in the history of the world. The perfection of the dynamo, and its twin brother the electric motor, by Wilde, Siemens, Wheatstone, Varley, Farmer, Gramme, Brush, Weston, Edison, Thomson, and others, soon brought the great development of the electric light and electric railways. Then appeared the Bessemer process of making steel; dynamite; the St. Louis bridge; the Westinghouse air brake; and the middlings purifying and roller processes in milling. That great chemist and probably greatest public benefactor, Louis Pasteur, added his work to this period; the Gatling gun appeared; great developments were made in ice machines and cold storage equipments; machines for making barbed wire fences; compressed air rock drills and the Mont Cenis tunnel; pressed glassware; Stearns duplex telegraph, and Edison's quadruplex; the cable car system of Hallidie, and the Janney car coupler; the self-binding reaper and harvester; the tempering of steel wire and springs by electricity; the Lowe process for making water gas; cash carriers for stores; and machines for making tin cans.

With the next decade (1876-1886) there arose a star of the first magnitude in the constellation of inventions. The railway and telegraph had already made all people near neighbors, but it remained for the Bell telephone to establish the close kinship of one great talkative family, in constant intercourse, the tiny wire, sentient and responsive to the familiar voice, transmitting the message with tone and accent unchanged by the thousands of miles of distance between. Then come in order the hydraulic dredges, and Mississippi jetties of Eads; the Jablochkoff electric candle; photography by electric light; the cigarette machine; the Otto gas en-

gine; the great improvement and development of the typewriter; the casting of chilled car wheels; the Birkenhead and Rabbeth spinning spindles; and enameled sheet iron ware for the kitchen. Next the phonograph of Edison appears, literally speaking for itself, and reproducing human speech and all sounds with startling fidelity. Who can tell what stores of interesting and instructive knowledge would be in our possession if the phonograph had appeared in the ages of the past, and its records had been preserved.

The voices of our dead ancestors, of Demosthenes and Cicero, and even of Christ himself speaking as he spake unto the multitude, would be an enduring reality and a precious legacy. In this decade we also find the first electric railway operated in Berlin; the development of the storage battery; welding metals by electricity; passenger elevators; the construction of the Brooklyn bridge; the synthetic production of many

№ 1.



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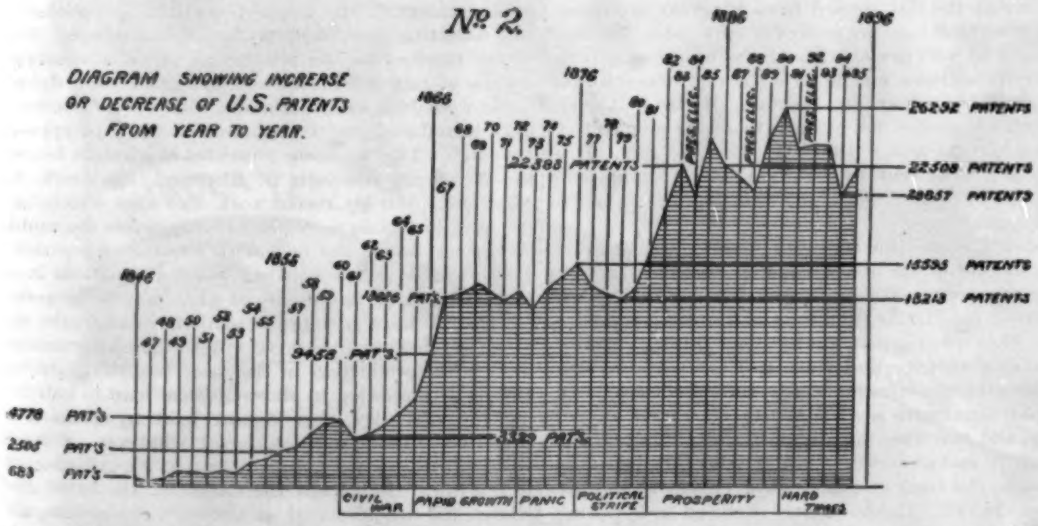


useful medicines, dyes, and antiseptics, from the coal-tar products; and the Cowles process for manufacturing aluminum.

In the last decade (1886-1896) inventions in such great numbers and yet of such importance have appeared that selection seems impossible without doing injustice to the others. The graphophone; the Pullman and Wagner railway cars and vestibuled trains; the Harvey process of annealing armor plates; artificial silk from pyroxyline; automobile or horseless carriages; the Zalinski dynamite gun; the Mergenthaler linotype machine, moulding and setting its own type, a whole line at a time, and doing the work of four compositors; the Welsbach gas burner; the Krag-Jorgensen rifle; Prof. Langley's aerodrome; the manufacture of acetylene gas from calcium carbide; the discovery of argon; the application of the cathode rays in photography by Roentgen; Edison's fluoroscope for seeing with the cathode rays; Tesla's discoveries in electricity, and the kinetoscope, are some of the modern inventions which still interest and engage the attention of the world, while the great development in photography, and of the web perfecting printing press, the typewriter, the modern bicycle, and the cash register is beyond enumeration or adequate comment.

Looking at this campaign of progress from an anthropological and geographical standpoint, it is interesting to note who are its agents and what its scene of action. It will be found that almost entirely the field lies in a little belt of the civilized world between the 30th and 50th parallels of latitude of the western hemisphere and between the 40th and 60th parallels of the western part of the eastern hemisphere, and the work of a relatively small number of the Caucasian race under the benign influences of a Christian civilization.

Remembering, furthermore, that most of this great development is of American authorship, does it not appear plain that all this marvelous growth has some correlation that teaches an important lesson? Why should this mighty wave of civilization set in at such a recent period, and more notably in our own land, when there have been so many nations far in advance of us in point of age? The answer is to be found in the beneficent institutions of our comparatively new and free country, whose laws have been made to justly regard the inventor as a public benefactor, and the wisdom of which policy is demonstrated by the growth of this period, amply proving that invention and civilization stand correlated—invention the cause and civilization the effect.

This retrospect, necessarily cursory and superficial, brings to view sufficient of the great inventions as milestones on the great roadway of progress to inspire us with emotions of wonder and admiration at the resourceful and dominant spirit of man. Delving into the secret recesses of the earth, he has tapped the hidden supplies of Nature's fuel, has invaded her treasure house of gold and silver, robbed Mother Earth of her hoarded stores, and possessed himself of her family record, finding on the pages of geology sixty millions of years existence. Peering into the invisible little world, the infinite secrets of microcosm have yielded their fruitful and potent knowledge of bacteria and cell growth. With telescope and spectroscope he has climbed into limitless space above, and defined the size, distance and constitution of a star millions of miles away. The lightning is made his swift messenger, and thought flashes in submarine depths around the world, the voice travels faster than the wind, dead matter is made to speak, the invisible has been revealed, the powers of Niagara are harnessed to do his will, and all of Nature's forces have been made his constant servants in attendance. We witness a new heaven and a new earth, contemplation of which becomes oppressive with the magnitude and grandeur of the spectacle, and involuntarily we find ourselves asking the question, "Is it all done? Is the work finished? Is the field of invention exhausted?" It does seem that it is quite impossible to again equal the great inventions of this wonderfully prolific epoch; but as these great inventions, which now seem commonplace to us, would have seemed quite impossible to our ancestors, we may indulge the hope of future possibilities beyond any present conception, but onward and upward in the great evolution of human destiny.

Rejoicing in our strength and capabilities, the new light of man's power and destiny breaks more clearly over us, and content with the infinite quality of mind and matter, the teachings of philosophy, and the facts of evolution, we rest in the assurance of positive knowledge that all that has been done in the past is merely preliminary, that human ingenuity knows no limit, and so long as man himself remains hedged about with the limitations of mortality and the conditions of growth, so long will his strivings and attainments be infinite.

BETA.

STEEL.

The term steel signifies iron containing a small percentage of carbon, and in modern times the term has become extended so as to indicate iron containing an almost infinitesimal amount of carbon, provided the metal is produced by the open hearth or Bessemer process. In the early ages of the world meteoric iron, a close representative of modern nickel steel, was used by the ancients. The art of producing iron in the primitive fining hearth, analogous to a blacksmith's forge, goes back to an early date. Then the blast furnace was invented, and cast iron, containing a larger percentage of carbon than steel contains, was produced. In the intense heat of the blast furnace, with its prolonged contact with the fuel and gases of combustion, the iron absorbed over two per cent of carbon. Such iron is termed cast iron.

With the exception of some special processes, the majority of steel in early days was produced from wrought iron. The latter was made from cast iron by the puddling process. The cast iron in the form of pigs was melted on the hearth of a reverberatory furnace in contact with iron cinder and iron ore, accompanied by constant stirring of the melted metal. The carbon was gradually oxidized, and wrought iron quite free from carbon was produced. This, after being worked down into shape by hammers and rolls, was inclosed in cases with shavings of horn and similar material and heated to a high heat for many hours. The metal absorbed carbon for the second time, and when removed from the boxes showed a blistered surface, and was termed blister steel. It was worked over to produce spring steel and shear steel, or was broken into pieces and melted in crucibles to produce cast steel, the crucibles holding from thirty to fifty pounds of steel.

Puddling involved a constant stirring and working of the metal with a pokerlike tool termed a rabble. This seemed to involve much labor, and many attempts were made to get rid of it. Various forms of mechanical puddling machines were manufactured, and about 1870 a great deal of attention was attracted by the American Danks rotary puddling furnace, the proof of which is given in the fact that it was elaborately examined in 1871 by a committee of English iron masters, who actually imported 40 tons of pig iron from England to test it with. This is cited to show the importance attached at so late a period to the old puddling process. It seemed obvious that, by puddling cast iron to a point when a portion of the carbon only was removed, steel might be directly produced; and the iron and steel world of the later sixties was intensely interested in the production of puddled steel, which then offered the only prospect of producing steel in large units. Many minor inventions were made in the production of steel until the world was ready to receive the monumental one, termed the "Bessemer process."

Sir Henry Bessemer early began his experiments on the production of steel from pig iron by the use of an air blast. His work was done principally in the fifties, and as evolved and developed by constant experiment, it took the shape of the following steps: Cast iron was melted in a cupola or a reverberatory furnace, and then was run into a vessel near whose bottom or in whose bottom were a number of blow holes, and through which, before the introduction of the metal, a blast under heavy pressure was maintained. The hot iron was run in, and as the blast was forced through it, its carbon and silicon were burned out and its temperature rose enormously, the carbon and silicon of the

iron forming the fuel. The original idea was to withdraw the metal when the carbon was sufficiently reduced. This, however, proved impracticable, except with exceedingly pure iron, although this process has been successfully carried on for many years in Sweden. The least trace of phosphorus impaired the quality of the steel very greatly, and eventually the system was adopted of blowing the metal to the complete exhaustion of the carbon and of then adding a weighed quantity of ferro-manganese or of spiegeleisen, which were practically cast irons containing a large portion of manganese and carbon. By varying the proportions of these materials added, steel of any required percentage of carbon could be produced. As the Bessemer process gradually came into use, it was seen that the manufacture of steel was revolutionized. It was introduced into this country, and Holley, newspaper reporter, mechanical engineer, and metallurgist, found it a fertile subject for his genius, and developed the mechanical features of the process by the introduction of the most perfect hydraulic machinery for operating it. The converter in which the metal is treated is now an egg-shaped vessel, mounted on trunnions, and of size to treat at once from one to fifteen tons of melted iron. Its bottom is full of holes for the blast. It is turned down on its side to receive the charge, the blast is turned on, and it is brought into an upright position for the blow. As the air passes through the melted iron contained in it, a vivid flame issues from its mouth, and the carbon and silicon are burned out of the iron. It is next turned down to receive the carbonizing charge of ferro-manganese or spiegeleisen, and the effect of any phosphorus present is partly overcome by the manganese thus added. The steel, which is as liquid as water under the intense heat, is poured into moulds, and by hammer and roll is worked into any desired shape. The old steel processes treated steel in units of a few pounds weight. The Bessemer process increased the units to many tons.

Something still was wanting; very pure iron had to be used, phosphorus being ruinous. In 1878, only seven years after the visit of the English metallurgists to America to examine the Danks puddling furnace, an announcement was made by a young man, Mr. Sidney Gilchrist Thomas, who stated that by the use of lime he had succeeded in reducing the phosphorus in the Bessemer steel process. After exhaustive experiments the following basic Bessemer process, as it is termed, was evolved, Thomas being associated in the work with his cousin Gilchrist. The Bessemer converter was lined with special bricks consisting largely of lime and of magnesia. After being heated up by a coke fire, a quantity of lime was thrown into the converter and was further heated.

The charge of iron was then introduced and the blow given with a period of some minutes of after-blow or of blast after the carbon was all gone. Spiegeleisen or ferro-manganese was added to give the carbon and the metal was poured. The effect of the after-blow in the presence of the basic material removed the phosphorus almost entirely and proved the greatest advance yet made in the Bessemer process. This brings us down to recent times. Incidentally it may be mentioned that the slag produced in this process is so rich in phosphoric acid that it is used to an enormous extent as a fertilizer.

In 1856 Sir William Siemens explained a steam engine of his invention to the Royal Institution, an invention representing ten years of experimental researches. It was an attempt to apply the regenerative system for saving heat. It was found to be without practical utility, because the high heat destroyed the machinery. A year later his brother Frederick suggested the employment of the system in a furnace. The hint was sufficient. Extensive experiments were at once begun and the Siemens regenerative furnace was the result. It was practically perfected about 1860, and Michael Faraday's last lecture in 1862 was devoted to it. In the Siemens furnace the fuel is burned in a gas producer. By the admission of insufficient air for complete combustion, a combustible gas, termed producer gas, is produced. The gas is admitted to the hearth of the furnace and burned there with heated air, the gas also being heated on the way to the furnace.

The essence of the Siemens invention lies in the way in which this heating is effected. The gas from the producer and the air for its combustion are caused to pass through chambers filled with intensely heated fire brick piled up loosely. The products of combustion before they leave the furnace pass through two other such chambers, thereby heating them. At short intervals, by the manipulation of valves, the course of the gas and of the air is changed, so that the products of combustion go through the chambers which have just been utilized for heating, thereby bringing them up again to a higher temperature, while the chambers already heated are used for the passage of the gas and air. By this process a sort of cumulative effect is produced. A most intense heat can be developed, and the economy effected is very large. Applications of the Siemens or open hearth furnace to making steel at once became obvious. By the Martin process, pig iron and wrought iron were melted together on the hearth, producing a steel of any desired percentage of carbon; by the Siemens process pig iron and iron oxide are used to produce steel on the open hearth, and in the Siemens-Martin process both methods are combined. The product of this operation is the famous open hearth steel.

The tendency of the present day is to produce open hearth and Bessemer steel of low carbon percentage, the metal from the chemist's standpoint being rather wrought iron than steel. It is produced in enormous quantities and the great ships and buildings of our days, the age of steel, are due to four great inventions of which three belong to the last half century. The hot blast for blast furnaces, invented in 1828 by James Neilson, doubled the output of the blast furnace without any extra fuel; in 1855 the Bessemer process was announced and the second of the inventions began to be applied; seven years later, or 1862, may be taken as giving the date of the third invention, the Siemens furnace; and the fourth invention, which we have placed in 1880, is the Gilchrist-Thomas or basic process of making steel from iron containing phosphorus. All other inventions in the metallurgy of iron and steel, ingenious as they were, practical as they were thought to be, with all their promise of great usefulness, sink into comparative obscurity when compared with these four epoch-making inventions which have so inconceivably modified our everyday life.

DISTINGUISHED INVENTORS.

Samuel Finley Breese Morse, the American artist, and the inventor of the electric telegraph, was the son of an American geographer; he was born at Charlestown, Mass., in 1791, and died in New York, April 2, 1872. In 1810 he graduated from Yale College, and in 1811 went to England with Washington Allston to study art under Benjamin West. In 1815 he returned to the United States, and in 1826 he was chosen as the first president of the National Academy of Design, which he was instrumental in founding. He was very fond of discussing electrical matters with his friend Prof. J. Freeman Dana; and while on a voyage from Havre to the United States in 1832, Morse conceived the idea of making not only an electric telegraph, but also an electro-magnetic and chemical recording telegraph, substantially as it now exists. Morse made some drawings on the steamer, which he afterward elaborated, but it was not until 1835 that he first exhibited a telegraph in operation, when he put a half mile of wire in coils around a room. In 1837 he filed a caveat in the Patent Office and also exhibited his new system in the University of New York. He asked Congress for aid to build a line from Baltimore to Washington, but nothing resulted. He went to England, where a patent was refused him. His French patent was worthless. It was not until March 4, 1843, that Congress finally granted $30,000 for his trial line. In 1844 the work was completed and Morse was able to show the practicability of his system of electro-magnetic telegraph. His patents were promptly infringed, and he was quickly engaged in an interminable succession of patent suits. At last these were decided in his favor, and he was able to reap the just reward from his great invention. Honors without number poured in upon him. Foreign nations vied with one another to give him medals or to confer decorations, and in 1858 the representatives of France, Russia, Sweden, Belgium, Holland, Austria and other countries met at Paris to decide on a collective testimonial, and $80,000 was voted to him. It is believed that he had the original idea of submarine telegraphy; he also made the first daguerreotype in the United States.

Elihu Thomson was born in Manchester, England, 1853, and at the age of five came to this country with his parents, who settled in Philadelphia, where he was educated, graduating from the Central High School in 1870. He experimented a great deal during his boyhood in electricity and chemistry, photography and similar subjects. Graduating at the age of seventeen, he spent six months as an analytical chemist in a laboratory, and was then appointed assistant professor of chemistry and physics in the high school, and was promoted to the chair of professor of chemistry and mechanics in 1876. He frequently lectured and continually experimented during this period, in the Artisans' Night Schools, Franklin Institute and elsewhere. He was associated with Prof. Edwin J. Houston in some patents relating to dynamos, and upon these and other inventions based the American Electric Company, since called the Thomson-Houston Electric Company, organized in 1880, and became chief electrician of the company. His invention of electric welding and brazing has been fully described in the columns of the SCIENTIFIC AMERICAN and SUPPLEMENT. His remarkable experiments in alternating current induction have done much to win for him an international renown. The air blast applied to switches and commutators for blowing away destructive arcs is a type of his practical way of reaching results. Like Edison, he holds a great number of patents.

Capt. John Ericsson was born in the province of Wermland, Sweden, in 1803, and died in New York in 1889. His father was a mining proprietor, so in his youth he had ample opportunities to watch the operation of machinery. He learned to draw, and entered the corps of Swedish engineers, and at twelve years of age was engaged in the construction of canals. He afterward entered the army and rose to be a captain at seventeen. During this time he made a small heat engine, which was the precursor of the hot air engine which he afterward successfully developed. His inventions in relation to locomotives were also important. Capt. Ericsson early began to make experiments on the screw propulsion of vessels, especially for war vessels, with the arrangement of the screw and all the machinery under the water line. He came to the United States in 1839, and in 1841 he became engaged with Commodore Stockton in building the United States frigate Princeton, said to be the first successful propeller war vessel with all its machinery under the water line. In 1833 he brought out the first practical hot air engine. He was also among the earliest constructors of steam fire engines. During the thirteen years that Capt. Ericsson lived in England he is said to have made forty new inventions. In 1828 he applied on the Victory the principle of condensing steam and returning the water to the boiler, and in 1832 he gave to the Corsair the centrifugal fan blowers, now generally used in American steam vessels. In 1830 he introduced the link motion for reversing steam engines on the locomotives King William and Adelaide, and in 1834 he superheated steam in an engine on the Regent's Canal Basin. Undoubtedly, the greatest of Capt. Ericsson's achievements was the building of the Monitor in 1861. This little iron gunboat, with revolving turrets, was so successful in the historic naval engagement at Hampton Roads in 1862 that it changed the whole course of naval construction throughout the world. Among his later inventions were torpedo boats and sun motors.

Elias Howe, the inventor of the sewing machine, was born at Spencer, Mass., in 1819, and died in Brooklyn, in 1867. He spent his time until 1835 on his father's farm and mill. He then went to Lowell and was employed in a manufactory of cotton machinery. He afterward worked in a machine shop in Boston. Here he developed his invention of the sewing machine. The first of his machines was made in May, 1845. He patented it September 10, 1846. After constructing four machines, he visited England in 1847, and remained there two years. From his return until 1854 he was involved in tedious lawsuits, but at last his rights were acknowledged and the former infringers paid him handsome royalties. He is said to have realized $2,000,000 from his invention.

Nikola Tesla was born at Smiljan, a small place on the Austrian border, and he is now 39 years of age. His education was received at Carlstadt in Croatia; he, too, showed the experimental bent and eventually entered the polytechnic school in Gratz, Austria. Here he studied engineering and devoted his spare time to studying electricity; on graduation he entered the engineering department of the telegraph at Buda-Pesth, and in 1881 took up the electric light and the construction of dynamo machines as his especial work. He is said to have been greatly impressed by the drawbacks incident to the employment of the commutator and collecting brushes on dynamos and motors. His efforts resulted in the production of an alternating system of power transmission, in which these drawbacks were done away with, and which is now universally introduced under the name of the "polyphase system." This work was presented in a lecture before the American Institute of Electrical Engineers, in May, 1888. But his recent work and that which has brought his name more prominently before the world than ever before has been with alternating currents. Employing a dynamo giving 20,000 alternations in a single second, he has produced what may be properly termed the most remarkable experimental results recently attained by electricity. With these alternations used in the production of the most beautiful lighting effects, he succeeded in showing or at least in indicating the possibility of producing light by means of a single or without any conductor whatever. Several striking features were brought out in his experiments in this line. He showed the nature of the brush discharge and demonstrated the necessity of excluding air and gas in general from induction coils and condensers. Many other effects of high frequency currents were pointed out, which have thrown novel light upon electrical phenomena. In recent years he has devoted his attention to the perfection of a method of lighting and other inventions, notably a method of conversion to currents of high frequency and the mechanical oscillators, which were first shown in an experimental lecture before the Scientific Congress at the World's Fair, Chicago, in August, 1893.

Alexander Graham Bell was born in Edinburgh, Scotland, March 3, 1847, being, therefore, almost the same age as Edison. He was educated at the Edinburgh High School and University. He came to the United States in 1872. His father and grandfather were both language teachers, and the young Bell's attention was directed to language by the course of studies prescribed by his father. The synthesis of artificial speech, by Helmholtz's method, is said to have early engaged his attention, and he resolved to pursue one of the outcomes of his studies, multiple telegraphy, to a practical conclusion. It has been said that all this

time the idea of speech transmission was an undercurrent of thought with him, and he has testified that, before 1870, he avowed his belief that we would one day speak by telegraph. Going through all sorts of experiments, he succeeded in inventing the telephone. He lectured on it before the Society of Arts, in Boston, May 25, 1876, exhibited it at the Centennial in Philadelphia, and in August of the same year speech, it was said, was transmitted over a telegraph line. He has received numerous honors, and has written numbers of papers on his other scientific work, such as the photophone. He has also for years studied the subject of speech for the deaf and dumb. After the shooting of President Garfield, Mr. Bell and Mr. Sumner Tainter experimented with the Hughes induction balance to find the bullet in Mr. Garfield, but their attempts proved futile.

Hayward A. Harvey, the inventor of the Harveyized steel armor plate process, passed away August 29, 1893, at his home in Orange N. J. Hayward A. Harvey was born in Jamestown, N. Y., January 17, 1824. His father was General Harvey, the inventor of the gimlet pointed screw, the cam motion, and the toggle joint. Young Harvey entered the office of the New York Screw Company as draughtsman in 1844, he took charge of a wire mill at Somerville, N. J., in 1850, and in 1852 he became connected with the Harvey Steel and Iron Company, of which his father was president. In 1865 Mr. Harvey founded the Continental Screw Company, of Jersey City. The inventions of Mr. Harvey, up to this time, had nearly all been in the direction of automatic machinery; but he afterward devoted his energies to metallurgical processes, and in 1888 he took out his first patent on a process for treating steel. This invention has now made his name familiar all over the civilized world, and has added another word to our language. The new process is, briefly, a method of hardening steel on the surface, or carbonizing it, and raising steel of a low grade to a higher one. The first armor plate treated by the Harvey process was made in 1890. The Harvey Steel Company was organized in 1889, and works were established at Brill's Station, near Newark, on the Pennsylvania Railroad. Various improvements were introduced in the manufacture of armor plates, and to-day Harveyized steel armor plates stand without a rival. The many tests prove conclusively

SOME DISTINGUISHED INVENTORS OF THE LAST HALF CENTURY.

that Harveyized steel plates are the best in the world. The construction of battleships has been modified by the introduction of Harveyized armor, and the new process is being adopted by the principal manufacturers of Europe. Mr. Harvey, in the course of a long and eventful life, had 125 patents granted to him.

Samuel Colt, whose name will ever be identified with the production of the revolver, was born at Hartford, Conn., in 1814, and died there in 1862. In his fourteenth year he ran away from school and went to sea. While on his East India voyage he made a model in wood of a revolving pistol. This was the germ of the great invention. After his return from Calcutta, he studied chemistry in the dye house of his father, and afterward traveled extensively in the United States and Canada, giving lectures on chemistry. He thus gained the means necessary to prosecute his invention of the revolver. In 1835 he visited England and France, taking out patents, and on his return he took out his United States patents. He established a factory at Paterson for the manufacture of his arms. There was, however, little demand for the new weapon, and the company became insolvent. During the Mexican war, in 1847, the manufacture of the revolvers was resumed—first at Whitneyville, Conn., and finally at Hartford. This last establishment was built on a very large scale, and made not only revolvers, but machinery for constructing the same, cartridges, etc. Mr. Colt also invented a submarine battery for the defense of harbors, and also a method of insulating submarine cables. In 1843 he laid a cable from Coney and Fire Islands to the city of New York, which was operated with success.

George Henry Corliss was born at Easton, New York, in 1817, and died in Providence, R. I., in 1888. He attended school until he was fourteen, and then became a clerk in a cotton factory; later he spent three years in Castleton Academy, Vt., and finally opened a country store at Greenwich, N. Y. He early showed a leaning toward mechanical pursuits, and in 1844 he moved to Providence, R. I., where, in 1846, he began to make improvements in steam engines. He patented what is now universally known as the "Corliss" engine in 1849. These improvements have revolutionized the construction of the steam engine. By the new devices the governor was connected with the cut-off, preventing waste of steam, and insured uniform speed under the most varying loads. A company was formed in 1856, and they adopted the novel plan of taking the saving in fuel for a given time as their pay. The large Corliss engine was one of the wonders of the Centennial Exposition, and is still in use, driving one of the largest manufacturing plants in the country. Mr. Corliss received many honors and decorations, and amassed a large fortune. He made many other minor inventions.

Thomas Alva Edison was born at Milan, Ohio, in 1847. He began life as a train boy, soon advancing to a newsdealer with assistants. He studied telegraphy and obtained a position as operator at Port Huron. He soon became noted for his speed and accuracy, his messages being taken down in handwriting like copperplate. He soon began to invent, and in 1864 he moved to Memphis and had one of his inventions, an automatic repeater, put into service. He struggled along, inventing and working at his profession, until he went to Boston in 1868, where he was able to open a workshop for developing his inventions. Shortly afterward he was retained by the Western Union Telegraph Company, and started an electrical laboratory at Newark, where he employed 300 men. In 1876 he moved to Menlo Park, New Jersey, and in 1887 left Menlo Park and erected in Orange, New Jersey, what is supposed to be the largest experimental laboratory of its kind in the world. His inventions, which are numbered by hundreds, center largely on electricity, although one of the most wonderful of his achievements is the phonograph. They include inventions in duplex and quadruplex telegraphy, the carbon transmitter telephone, the incandescent lamp, the electric railroad, the electrophone, the motograph for accelerating speed in ocean cabling, the microtasimeter, the odoroscope, the megaphone, the phonoplex telegraph, the pyro-magnetic motor and generator, the magnetic bridge, the electric pen, dynamos and motors, the kinetograph, the magnetic ore separator, and last of all the fluoroscope and the new vacuum light. Taken all in all, the inventions, both from quantity and value, place Mr. Edison in the very front ranks of the inventors of all ages, and it is gratifying to note that he has reaped both honors and rich rewards for his discoveries.

Cyrus Hall McCormick, the inventor of the reaping machine, was born at Walnut Grove, Va., in 1809. He died in Chicago, in 1884. His education was obtained in the common schools; he also helped his father in farm work, and at the age of fifteen had constructed a cradle used in harvesting in the field. At the age of twenty-one he invented two new and valuable plows. As far back as 1816 his father made attempts to construct a reaper, but these attempts only ended in failure, but in 1831 young Cyrus proceeded on a new line, and succeeded in making a success of the new grain harvesting machine which was to bring him fame and fortune. He patented his reaper in 1834, and improvements on it in 1845-47 and in 1858. In 1847 he moved to Chicago, where he built a large plant. He received numerous awards for his invention, which also obtained for him a large fortune. He was elected a corresponding member of the French Academy of Sciences, "as having done more for the cause of agriculture than any other living man." It was estimated in 1859 that his invention saved the country at least $55,000,000 per annum. Of course, with the growth of improvement, this sum has been largely augmented.

AMERICAN SHIPBUILDING.

Though the history of American shipbuilding has been marked by many fluctuations, there had never been a time, from the colonial days of the seventeenth century down to the sudden decline of the middle of the nineteenth century, when it had not been in a more or less healthy condition. The records show that fifty years ago we had entered upon the last and most brilliant era of shipbuilding which the country has ever seen. In the three years, 1843 to 1846, the total yearly tonnage built in the United States had risen from 63,888 to 108,203 tons. In 1850, 279,255 tons were built, and in 1855 the total rose to 583,450 tons. So rapid was the growth that by the year 1860 there was a total of 5,353,868 tons in the merchant marine, 2,379,396 tons of which were engaged in the foreign trade. At this time the total tonnage of the British empire was only slightly greater—5,710,968 tons.

It was inevitable that an enterprising country, with a 3,000 mile Atlantic seaboard flanked by great forests of timber that was excellently adapted to shipbuilding, should create a powerful merchant fleet; and the rapid decline which took place at this time is primarily to be ascribed, not to any decadence of the maritime spirit, but to the substitution of iron for wood in the construction of ships; though the collapse was undoubtedly hastened by the outbreak and course of the civil war.

As long as wood was the material of construction the American shipwright more than held his own against the world; but the change from wood to iron came a little too early for the undeveloped condition of the mineral resources of the United States, and we suffered accordingly. In 1855 there were built 381 ships and barks and 126 brigs; in 1870, only 73 ships and barks and 27 brigs; in 1880, but 23 ships and barks and 2 brigs; and in 1895, 1 ship. Of steam vessels we built in 1846 some 46,359 tons; 147,499 tons in 1864, and 69,753 tons in 1895. The above figures, it is true, do not include schooners and sloops, nor the large fleet of canal boats and barges, of which there were 445 built in 1895, with a total tonnage of about 41,000 tons.

In addition to the two causes of decline above mentioned, it must be remembered that the past thirty years has been a period of unparalleled agricultural, mining and manufacturing activity. If the nation has neglected its merchant marine, it has been largely for the reason that it was fully occupied with the development of the internal resources of the country. The discovery of the gold fields of California; the rapid extension of the railroads, and the opening up of the unoccupied farming lands of the West; the development of the mineral wealth of the country, and the rapid growth of the iron industries, have proved a strong counter attraction that has temporarily weaned the heart of the nation away from its old-time love of the sea. Now that the tide of emigration has touched the remotest bounds of the country, and the extent of its resources has been well ascertained, we may look for something of a reaction in the direction of maritime enterprise—indeed, the reaction has already begun.

The teachings of history regarding the relation of the navy to the merchant marine have frequently shown how intimately the interests of the two are associated. A large merchant fleet requires a strong navy for its protection, and a strong navy can never exist without a large merchant marine, from which, in the sudden emergency of war, it can recruit its seamen.

We think that, when the history of American shipbuilding comes to be written, it will be agreed that two of its red letter days occurred on July 23 and 26, 1883, when the celebrated firm of John Roach & Sons, of Chester, Pa., signed the contract for the construction of the Atlanta, the Boston and the Chicago, and the Dolphin, ships which were to prove the forerunners of a completely new and up-to-date navy. The policy which was thus commenced has encouraged our shipbuilders and engineering firms to lay down extensive and costly modern plants, suitable for the building of the most approved modern ships and engines. So utterly stagnant was the shipbuilding industry that it needed some powerful stimulant to arouse it. The prospect of securing contracts for warships, as they shall from time to time be built, has not only encouraged the existing yards to enlarge their plants, but has called others into existence; until to-day we have several firms which are qualified to undertake the construction of the largest merchant steamers, and, as the performance of the St. Paul and St. Louis has clearly shown, to rival the best work of the European builders.

The last census showed that there were in all 1,000 shipbuilding plants in the United States, though, of course, many of these are comparatively insignificant. The important yards are located on the seaboard and on the great lakes, the latter locality having witnessed of late years the growth of a really magnificent steam fleet.

The history of the Pacific fleet dates from the year 1849, when the Union Iron Works had its beginning in a small forge at San Francisco. In 1865 the name of the firm was changed to Prescott Scott & Company, and in 1885, when the fine yard in South San Francisco was opened, the firm became known as the Union Iron Works. This new yard and works is one of the most complete of its kind in the world. The buildings, which are of brick, cover an area of four acres, the total area of the covered works being nine acres. One of the most notable features is the hydraulic dry dock, with an area of 30,450 square feet, which we hope to illustrate in a later issue. The works are underlaid throughout with hydraulic mains, which supply the various lifting, forging, shearing and riveting machines. The Union Iron Works give employment to 1,500 men, and they have turned out some of the most successful ships of the new navy, including the Charleston, San Francisco, Monterey, Olympia and Oregon, in addition to many fine ships for the merchant service. To this firm, aided by the various smaller yards scattered along the coast, must be given the credit of a fleet on the Pacific Ocean which comprises some 1,520 American vessels, aggregating 456,359 tons.

Coming across to the Atlantic seaboard, we should take note in passing of the Iowa Iron Works, Dubuque, Iowa, where the steel torpedo boat Ericsson, of 120 tons and 24 knots speed, was built. There is a world of suggestiveness in the fact that this destructive little craft was built and engined thousands of miles up the Mississippi, and dispatched to the Atlantic by way of New Orleans.

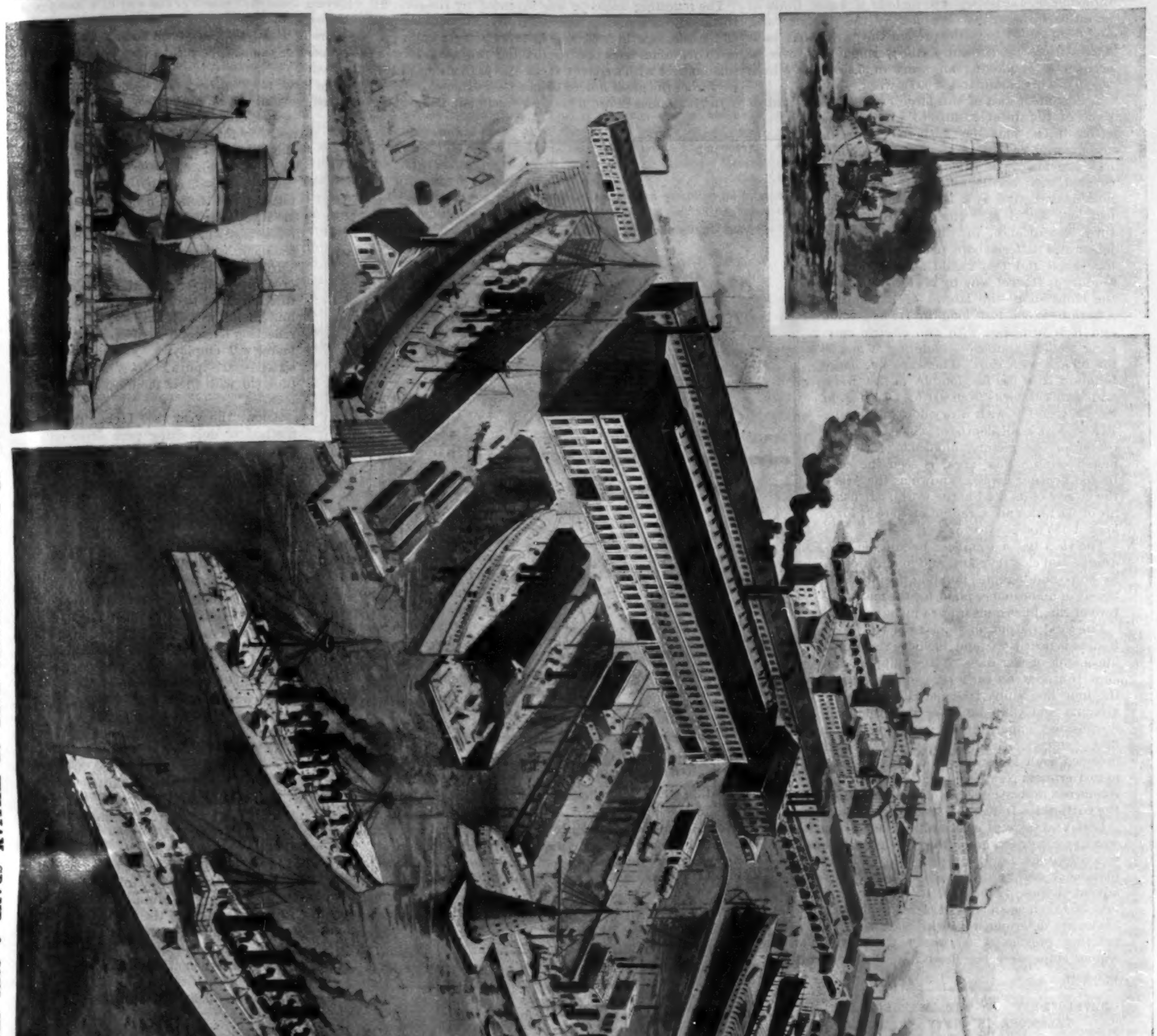
Turning northward to the great lakes, we find that American shipbuilding has advanced by leaps and bounds, and that here, in its inland seas, it has to record a growth of which it may justly be proud. In 1895 our lake shipping comprised 3,342 vessels, with a total tonnage of 1,241,459 tons, two-thirds of this tonnage consisting of steam vessels. The Commissioner of Navigation estimates that the carrying power of this fleet is 2,666,261 tons, in which case our merchant fleet on the lakes alone is larger than that of France, and second only to England and Germany. It only requires a full-sized ship canal to enable the splendid shipyards that fringe the lakes to lend their aid to building up a deep sea fleet that shall be second to none in the world.

Passing on to the New England coast, renowned for its famous yards in the days of the wooden sailing ships, we find a compact and very complete plant at the Bath Iron Works, Bath, Maine. It covers a large area on the banks of the Kennebec River, twelve miles from its mouth. Several vessels for the new navy, including the ram Katahdin, have been launched from its slips. City Point Works, Boston, Mass., and the Herreshoff Manufacturing Company, of Bristol, R. I., have contributed to the list of our merchant and naval fleets, and the latter firm have immortalized themselves in the international yachting world by the production of such craft as Vigilant and Defender. Mention must be made also of the Columbian Iron Works, Baltimore, Md., N. F. Palmer & Company, of Chester, Pa., of Harlan & Hollingsworth, of Wilmington, Del., and many other yards that are contributing to our increasing fleet of deep sea and river craft.

One of the clearest evidences of the faith of American capitalists in the revival of our maritime interests is to be found in the extensive and costly plant of the Newport News Shipbuilding and Dry Dock Company. This concern, like the town from which it is named, has been built up within a very few years. Its extensive shops, dry docks, and building ways have been carefully laid out after a thorough inspection of the great shipbuilding yards of the world. It has turned out some fine ships for the merchant service, and taken an active share in the construction of the new navy, the gunboats Wilmington, Nashville and Helena, which have been constructed in this yard, being just about to be turned over to the government. Here also are being built the Kentucky and Kearsarge, first-class battleships of 11,525 tons, an illustration of which, as they will appear when completed, will be found on another page.

The plant comprises sixteen buildings, which include four shops 100 by 300 feet, and a blacksmith's shop 120 by 208 feet in size. There are four piers ranging from 60 by 350 feet to 60 by 900 feet in size. The plant includes eight ship ways from 400 to 500 feet long, and an outfitting basin 500 feet by 900 feet. There is also a dry dock 600 feet long, with a depth of 25 feet over the sill. Over 3,000 men find employment in the various departments.

There is no shipbuilding concern in America that has contributed so largely to the upbuilding of our modern navy and the merchant marine as the William Cramp & Sons Ship and Engine Building Company, of Philadelphia, Pa. The foundation of this justly famous concern dates from the year 1830, when Mr. William Cramp, then a young man of 23 years, opened a small shipyard at the foot of Otis Street, Philadelphia. That was the age of wood and canvas, and for forty years William Cramp continued to build sailing ships for home and foreign service. In 1871-72 the es-



BIRD'S EYE VIEW OF THE SHIPBUILDING YARD OF WILLIAM CRAMP & SONS, SHOWING WAR VESSELS CONSTRUCTED BY THEM.

tablishment was enlarged to include a water front of about half the length occupied by the present yard, and from that date to the present the growth has been a steady one, the present yard covering a little over 31 acres, and employing an army of 5,600 men, whose wages alone amount to $54,000 a week.

An excellent idea of this large establishment, and of some of the notable ships to which it has given birth, may be gathered from the accompanying bird's eye view. The buildings are mainly of brick, or of steel frames covered with corrugated iron. The most notable structure is a large building 1,164 feet long by 72 feet wide, and from two to three stories high, in which are included joiner and pattern shops, machine and erecting shops and two mould lofts. The iron foundry is 415 feet long by 264 feet wide, and the boiler shop—the largest of its kind in America—is 387 feet long by 112 feet wide, and it is furnished with two electric traveling cranes capable of handling 70 and 90 ton boilers with ease. There are five large building slips 600 feet long by 75 feet wide, and five wet docks from 600 to 1,000 feet in length, together with a dry dock 462 feet by 70 feet, with a sill depth of 22 feet. In the center of the picture, alongside of the armored cruiser New York, is seen the celebrated floating derrick, known as the Atlas, the largest of its kind in the world. It has a lift of 60 feet, and a radius of 35 feet, for a load of 125 tons.

The yard has a complete pneumatic, hydraulic and electric plant, and in addition to its ship and engine building facilities, it boasts of an ordnance plant for the manufacture of rapid-fire guns up to 4 inches caliber.

The total output of ships from this yard to date is nearly 300, and includes the Morning Light of the days of the clipper; the New Ironsides, an early broadside ironclad; the four fine ships Indiana, Illinois, Pennsylvania and Ohio, built for the American Steamship Company in 1872; and a veritable fleet of ships for the new navy, in which is included such famous creations as the armored cruisers New York and Brooklyn, the commerce destroyers Minneapolis and Columbia, and the battleships Indiana, Massachusetts and Iowa.

Last, and perhaps most brilliant achievement of all, was the construction of the two great transatlantic steamships, St. Louis and St. Paul, of 11,629 tons displacement, and 20 to 21 knots sustained sea speed. The advent of these twin ships to the transatlantic route may be taken as an earnest of the fact that the United States are determined to win back something of the old time prestige, which was hers when her clipper ships were the fleetest that crossed the seas.

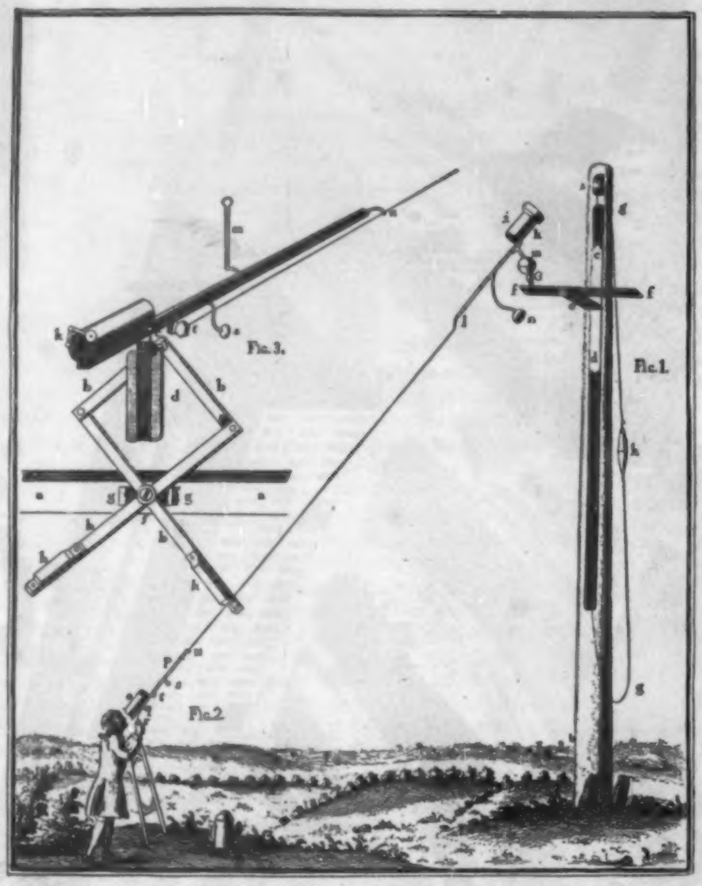
DEVELOPMENT OF THE ASTRONOMICAL TELESCOPE IN FIFTY YEARS.

Like almost every great invention dating back a century or more, it is very difficult to obtain data of a positive character regarding its early history. It will be useless in an article of this nature to speculate on the indirect evidence that may be gathered from the writings of Greek and Latin authors, but from such writers as Roger Bacon we are able to obtain information of a very satisfactory nature regarding the properties of lenses.

Mention is made of the use of lenses in "Pantometria," by Thomas Diggs, in the sixteenth century. Dee's preface to an edition of Euclid, published by him in 1570, has some remarkable passages on the use of lenses. Batista Porta, in a work published by him in 1561, describes a combination of concave and convex lenses. Henry Lippershey, about 1607, seems to have the best evidence on his side as the inventor of the telescope. In 1609 Harriot made observations on celestial phenomena with an instrument probably made in England, and Sir William Lower, a Welshman, asked Harriot to procure a cylinder (telescope) for him. Galileo, in the same year, learning that the telescope had been invented, made one. Afterward he made a larger one, with which the greatest astronomical discoveries ever recorded were made. Kepler improved the instrument by substituting a convex for a concave eye lens. Huygens made a telescope in 1655 having a focal length of 12 feet, with which he discovered Titan, Saturn's largest moon. His brother made telescopes 107 and 210 feet focal length. About the same time Campani, at Bologna, and Divini, at Rome, were making fine lenses of 90 to 130 feet focal length.

The reflecting telescope was invented by Gregory, in the middle of the seventeenth century. Newton invented his telescope in 1666, and in 1672 Cassegra improved the Gregorian telescope by making the secondary or small mirror with a convex surface, so as to intercept the rays from the great mirror before they came to a focus.

In 1732 James Short, a young Scotchman, made glass reflectors, silvered on the back; but he soon substituted speculum metal for glass. About forty years later Sir William Herschel commenced his wonderful career as an astronomical telescope maker, producing beautiful mirrors of speculum metal from 6 to 48 inches in diameter. Contemporaneously Schroeter, in Germany, made some excellent reflecting telescopes, and, like Herschel, made many interesting observations with instruments of his own construction.



HUYGENS' AERIAL TELESCOPE, 1655.

Having done thus much in the way of a hasty review of the early history of the telescope, we will state a little more in detail what has been done in the way of development of the astronomical telescope within the last fifty years.

From 1840 to 1845 Lord Rosse designed and constructed several large and powerful reflecting telescopes, one of which was six feet diameter and fifty-four feet focal length. The work of this telescope upon nebulæ and star clusters has become historic.

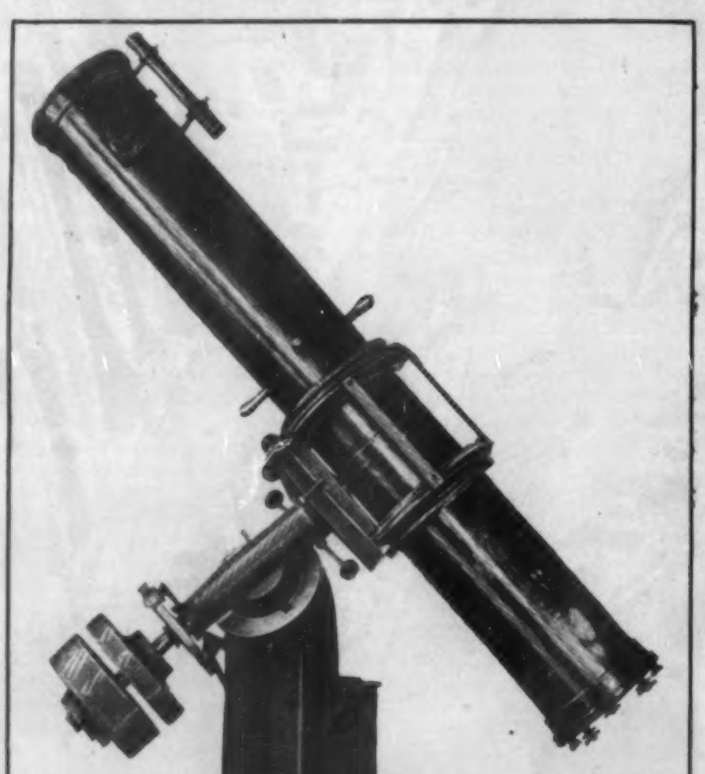
In 1861 Lassell erected his great reflecting telescope on the island of Malta, and Dr. De la Rue constructed several fine reflecting telescopes which he used in photographing the moon, etc.

In 1868 Mr. Thomas Grubb finished the great Melbourne reflecting telescope. For this telescope two 48 inch mirrors of speculum metal were furnished. In almost all reflecting telescopes used up to 1854 speculum metal was employed. This is composed of sixteen parts pure copper, fifty-eight parts pure tin, with slight modifications by various makers.

About the year 1850 Liebeg discovered a method of depositing pure silver on a glass surface. In 1856 Steinheil took advantage of this fact and was perhaps the first to make the now well known silver on glass specula, in which the silver is deposited on the first surface, which has been accurately polished and corrected before the silver is deposited upon it. A year later Leon Foucault described his method of making silver on glass mirrors, and made with his own hands many beautiful surfaces. By this method M. Eichens made the 48 inch mirror for the Paris Observatory, and a few years later Dr. Henry Draper made the 15 inch silver on glass telescope with which he obtained such beautiful results in lunar photography. Later on he constructed a silver on glass telescope of 28 inch aperture, by which he photographed the spectra of stars for the first time. These telescopes are now mounted at Harvard College Observatory. Dr. Draper published a most valuable monograph on the silvered glass telescope in 1864, and by its aid hundreds of amateurs have made very creditable reflecting telescopes.

But we must go back to the middle of last century to record what proved to be the greatest invention of the age in the way of developing the refracting telescope. Notwithstanding Newton's dictum that it was useless to try to improve it, owing to the impossibility of producing refraction without dispersion, Euler read a paper before the Berlin Academy in 1747 proving mathematically the possibility of correcting both the spherical and chromatic aberration of an object glass; and curious to say, the very man who published an adverse criticism of Euler's paper was no less a person than the celebrated John Dollond, who is recognized as the father of the achromatic telescope, for upon reading Klingenstierna's paper corroborating Euler's views, Dollond made a series of most valuable experiments which led him to the solution of the problem of the achromatic object glass; namely, that by properly combining two kinds of glass, flint and crown, he could unite the colored rays fairly well and still have refraction to unite the incident rays to form an image. Here we could fill a column with many interesting items of Dollond's work, but lack of space forbids. It is true that when Dollond applied for a patent to protect his discovery, it was claimed that Chester Hall had invented the achromatic objective as far back as 1829; but Lord Mansfield, who tried the case, remarked, "It was not the person who locked his invention in his scrutoire that ought to profit for such invention, but he who brought it forth for the benefit of the public."

Dollond's work soon became famous. He was surely master of it and had a clear field for many years, but he labored under great difficulties in procuring glass suitable for telescopes of any diameter. The writer has read an original letter from Dollond to Prof. Loomis, of Yale, in which he asked three years for the completion of a five inch telescope. Fortunately a genius had taken hold of this problem in the person of Guinand, a Swiss watchmaker, the story of whose life work is as charming as that of Palissy the Potter. After long experimenting, Guinand solved the problem of making fine disks of optical glass, and having associated himself with the celebrated Fraunhofer, in 1805 successfully made optical glass disks up to fifteen

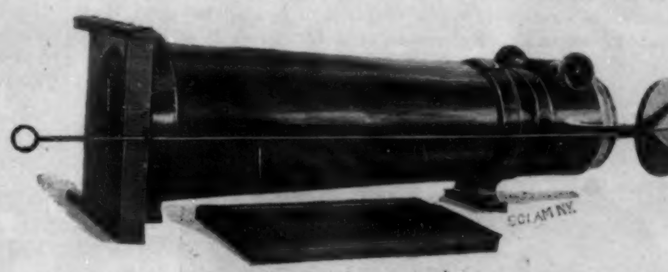

REFLECTING TELESCOPE.

inches aperture. To Fraunhofer we owe many of the most important discoveries in the theory of the achromatic objective, and it is sad to record that his brilliant career was cut off by his death at the age of thirty-nine. Foucault died at the same age, but both men during their short lives added to the world's records an immense fund of invaluable data in mathematical and practical optics.

The then great telescopes of Cambridge, Mass., and Pulkova, Russia, were made by Merz and Mahler, the successors of Fraunhofer. Contemporary with the progress of practical optics, mathematicians were developing theories of a critical nature, and the names of Gauss, Littrow and others must always be associated with this great work. In France Lerebours and Cauchoix were making excellent achromatic objectives. In England, Simms; in Ireland, Thomas Grubb, were taking an active part in the charming work; while in America, the Clarks had commenced their great work; first on reflecting and afterward on refracting telescopes. Every American has a personal pride in the work of the Clarks, and their objectives soon became famous in every part of the world for their accuracy of figure and fine definition. But one of this firm is now living, Mr. Alvan G. Clark, who has recently finished the great objective of the Yerkes Observatory, the largest objective yet constructed. There are but two firms in the world who have attempted to furnish the glass disks for these great telescopes—Mr. Mantois, of Paris, successor to M. Feil, and Dr. Schott & Company, of Jena, in Germany; but Macbeth & Company, of Pittsburg, Pa., have lately succeeded in making optical glass up to 20 inches diameter, of very excellent quality. To-day we have in France the eminent opticians the Henry Brothers, who have made many large and fine objectives; Secreton & Bardou, who have constructed many excellent telescopes of smaller size. In Germany Merz still sends out some good objectives, while Steinheil & Son are making objectives of the highest type. In England Messrs. Cooke & Company are doing splendid work, while in Ireland Sir Howard Grubb is turning out many fine telescopes of large size. In America Mr. Alvan G. Clark, of Cambridge, Mass., is the successor of the firm of Alvan Clark & Sons. Mr. Henry Fitz made a large number of the older glasses and the Spencers have contributed several large objectives to American observatories. Mr. Clacey, of Washington, has also made a few excellent objectives of good size. Indeed, there have been quite a number of objectives made by American amateur workers that have proved to be worthy of the makers. In Allegheny, Pa., John A. Brashear has been engaged in the development of the achromatic objective from new and valuable formula devised by Dr. Charles S. Hastings, of Yale University.

In the mounting of great telescopes, engineering problems of a difficult nature have had to be met, and to the mechanician we must accord a place of honor in the development of the telescope; for, when it is taken into consideration that such a telescope as the 36 inch at the Lick Observatory weighs forty-five tons, and the 40 inch of the Yerkes Observatory weighs nearly seventy-five tons, and that the great tubes of these instruments must move with the utmost precision, aye "keep time with the stars," it is easy to comprehend that the engineering problems are intricate and difficult of solution. But our astronomical engineers have been equal to the task, and have brought the mounting of the telescope to the highest perfection. In France we have Gautier; in Germany, the Repsolds; in England, Cooke; in Ireland, Sir Howard Grubb; in America, Messrs. Warner & Swasey, of Cleveland, O., and Mr. Saegmuller, of Washington. The largest instrument mounted by Mr. Saegmuller is the 20 inch of the Denver University. Messrs. Warner & Swasey constructed the 36 inch (an illustration of which appeared in our issue of June 16, 1888) Lick telescope mounting, the 40 inch of the Yerkes Observatory, and many of the larger telescopes that have been constructed of late years. Constant efforts have been made to lessen the work of the observer in handling the "magic tube," and perhaps no better type has yet been constructed than the new mounting for the 26 inch equatorial of the United States Naval Observatory, an illustration of which is here given. This mounting is what the engineer would call "clean," as it has no useless appendages, but has everything needed for use of the observer. This mounting has been constructed recently by Messrs. Warner & Swasey, of Cleveland, O.

A new type of telescope has of late years come into prominence as an "astronomical weapon," i. e., the photographic telescope. There are two general forms; one as adopted by the Photographic Congress for small but accurate fields of stars, which is to be used to obtain a photographic chart of the entire sky, the other for wide field "picture" photography. The eye at the telescope receives an impression from the light coming from a star and dismisses it, so that by long gazing we see no more stars than by a brief glance. Not so with the photographic plate. Every tiny ray sticks to the plate, and if the astronomical camera is held long enough upon the stars in the field, the images become imprinted by thousands—images of stars no telescope will ever show to the eye. The writer has seen on a plate 14 × 17 inches not far from fifty thousand stars photographed by Dr. Gill, of the Cape Observatory. Prof. Barnard, when at the Lick Observatory, used the photographic telescope in most valuable studies of comets and star clusters, while Dr. Max Wolf, of the Heidelberg Observatory, has discovered many new asteroids by the aid of this wonderful tool of the modern astronomer.



ASTRONOMICAL PHOTOGRAPHIC CAMERA, WITH DOUBLE OBJECTIVE, FOR WIDE FIELD PHOTOGRAPHY.

To Dr. Lewis Rutherfurd we owe the principle of the refracting telescope as applied to purely photographic purposes, and the instrument made by his own hands is typical of all that have followed in this line. The reflector had already been used for photography and still holds an important place for this kind of astronomical work.

The spectroscopic discoveries of Wollaston and Fraunhofer, as well as those of Herschel, Fox-Talbot and Brewster, were made several years previous to the period we have under consideration. After 1849, however, through the efforts of Foucault, Kirchhoff and others, the coincidence of the absorption bands and bright lines of the spectrum was established, and upon this discovery was based the star spectroscope, by means of which so many brilliant astronomical discoveries have been made. This instrument, as improved by Kirchhoff, Bunsen, Huggins and others, has been the means not only of revealing the constitution of the sun, stars, comets and nebulæ, but the condition of matter of which these bodies are composed.

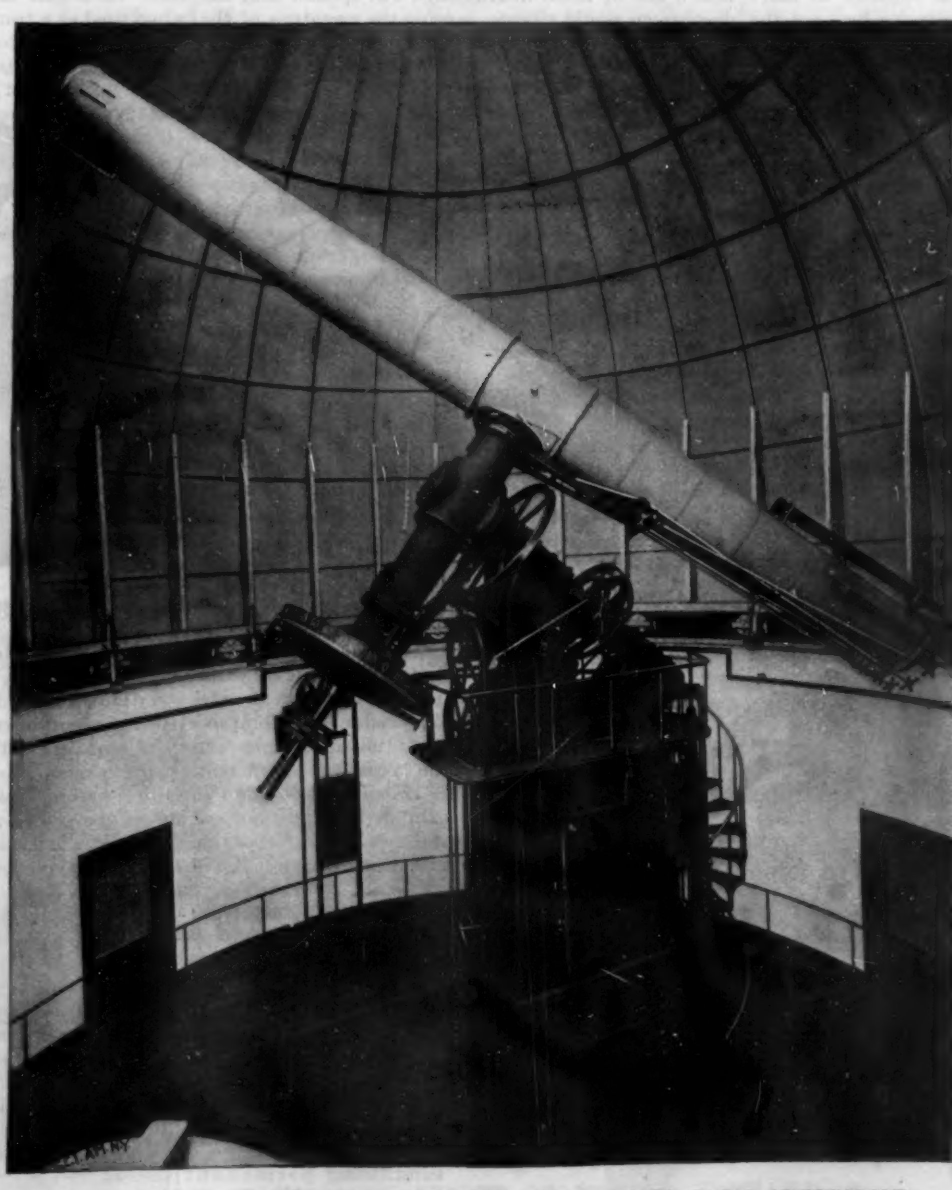
Spectroscopic observations of the motions of the stars in the line of sight yield results of the highest importance. By a single observation it can be determined whether the star is approaching or receding, and with what velocity. By the union of this method with the ordinary telescopic method, even though the path of the stars should cross the field of vision at any angle, the velocity of the star and the direction of its movement can be determined, provided the distance of the star is known. The spectroscopic method of measuring the velocity of stars has only recently been put in practice.

By the use of the photographic plate in connection with the spectroscope, extremely close binary systems have been discovered which would certainly never have been known if the ordinary telescope alone were available.

But the half has not been told. When we compare the little telescope of Galileo with the majestic 36 inch of the Lick Observatory, we think of the mighty step from one to the other, but it has all come along slowly through the years of the past until further progress would seem to be limited by our environment. The writer is not willing to say that we have reached this limit, either in optical or engineering problems, as master minds still look and hope, and are now working for new discoveries in the realms of optical science.

THE TELEPHONE.

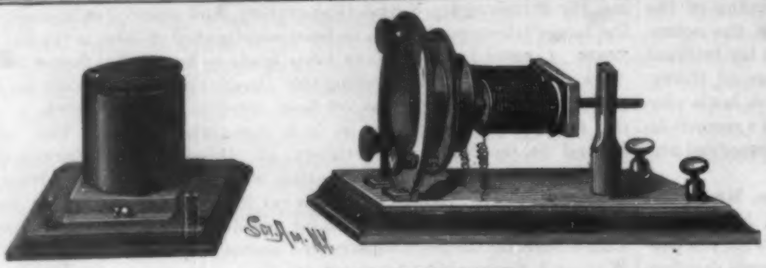
In the early days of the telephone no one seems to have conceived of the possibility of transmitting speech by electricity. Natural as the idea might seem, it apparently transcended any one's imagination up to a comparatively recent period. Page had discovered, in 1837, that an iron bar magnetized and demagnetized emitted sounds, and he went no further. Over twenty years later, about 1860, Philip Reis, a German school teacher, was experimenting on a telephone which, in his hands, took various shapes, always, however, having a different construction of the receiver and of the transmitter. His receiver had a diaphragm bearing at the center a contact piece. The diaphragm was caused to vibrate when acted on by the voice, and Reis relied on the effect on the contact to cause vibrations in the current, the latter being produced by a battery. In the same circuit was placed his receiver, one typical form being a knitting needle wound with a coil of wire and mounted on a sounding box. The apparatus was first shown at a seance of the Physical Society of Frankfurt, in 1861. Reis believed that his instrument could transmit words, and he is reported to have said that he had shown the world a road to a great discovery, but left it to others to follow it up. He died in 1874. All that was wanted to make his telephone a success was the substitution of carbon for one or both of the metallic contact points which he employed. Numerous variations of his construction may be found, but what has been said about



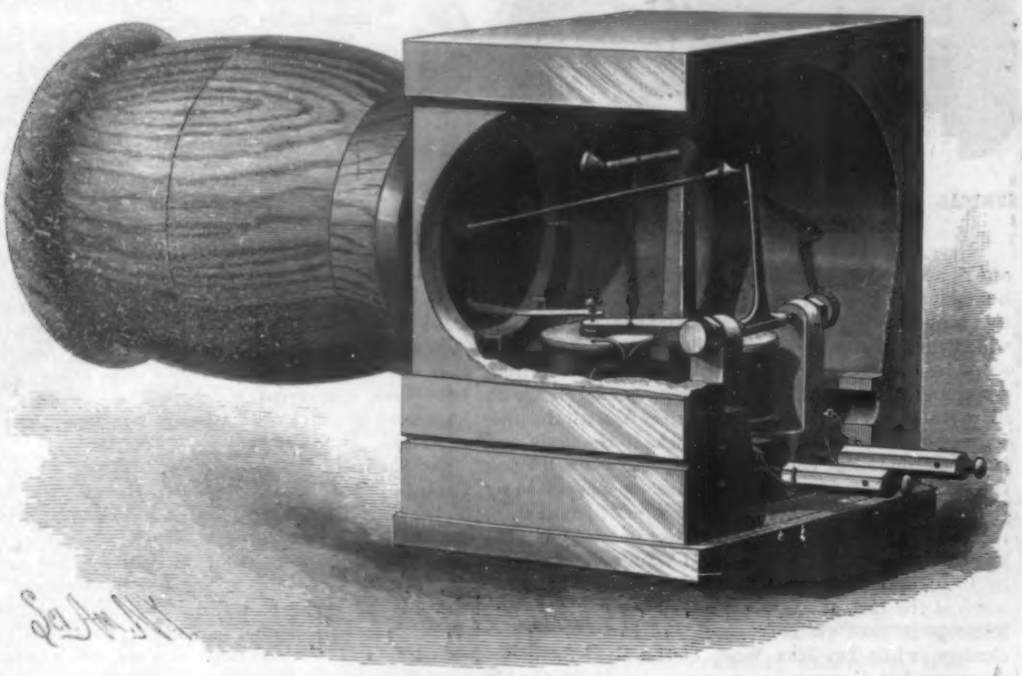
TWENTY-SIX INCH EQUATORIAL REFRACTOR UNITED STATES NAVAL OBSERVATORY.

it gives the general idea. Many other investigators experimented with his telephone.

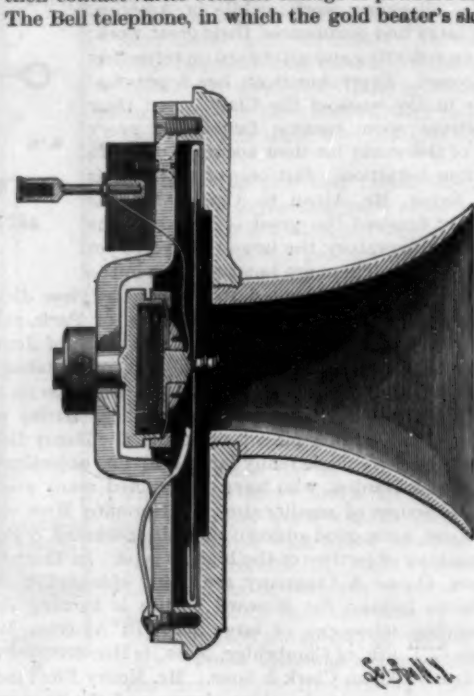
About 1868 Royal C. House, an American inventor whose printing telegraph had awakened universal interest, invented what he termed an electro-phonetic receiver for his telegraph. His idea was to produce an instrument which, precisely like the modern telephone, would produce an audible sound upon receiving a weak current of electricity. It consisted of a box closed with a diaphragm, against which two rods were pressed endwise by the rocking or pivoted armature of an electromagnet, so that in its motions the armature would alternately push against one or the other rod. The electromagnet was actuated by weak currents, and an ear placed opposite an ear piece leading to the diaphragm received the sound. This instrument is a telephone far superior to Bell's original invention, although its inventor had not the least idea of its capabilities for the transmission of articulate speech.



BELL'S EARLY TELEPHONE.



THE HOUSE TELEPHONE.

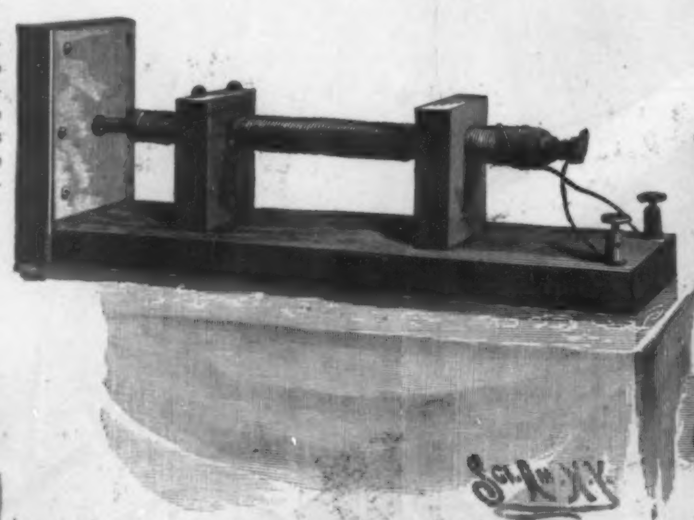


MODERN CARBON OR MICROPHONE TRANSMITTER.

Eight years later, Elisha Gray, of Chicago, and Graham Bell, of Boston, were working on the problem of the transmission of sound by electricity, and on the 14th of January, 1876, Bell took out his patent for his first instrument. The receiver and transmitter in it are identical in their essential features, each consisting of an ear or mouth piece, over whose end a diaphragm is stretched, which diaphragm is made of gold beater's skin. By means of a little rod it is connected to the oscillating armature of an electromagnet, and a battery is included in the circuit. The assumption was that if one of these instruments was spoken into the diaphragm would vibrate, causing the armature of the magnet also to vibrate, thereby introducing variations in the current so as to reproduce the vibrations from the diaphragm into the receiving instrument. In the summer of 1876 Bell exhibited his telephone at the Centennial Exposition in Philadelphia. It varied somewhat from the instrument of his patent. The transmitter was a vertical electromagnet with a plate armature, which was spoken against by the person sending the message. It worked with the utmost difficulty, but speech was transmitted. The next improvement took the shape of omitting the battery and substituting permanent magnets therefor. It was found that identical instruments could be used for receiving and sending, each consisting of a permanent magnet wound with a coil of wire, near the poles of which magnet a thin diaphragm of iron was held. By speaking against one of the diaphragms it was caused to vibrate, thereby inducing currents in the line connecting the two coils and causing the second diaphragm to repeat the sound uttered in the first. Almost at the same time with Bell, Gray had worked upon the telephone system, using a varying liquid contact, made to vary by the vibrations of a diaphragm and thereby producing the speaking current.

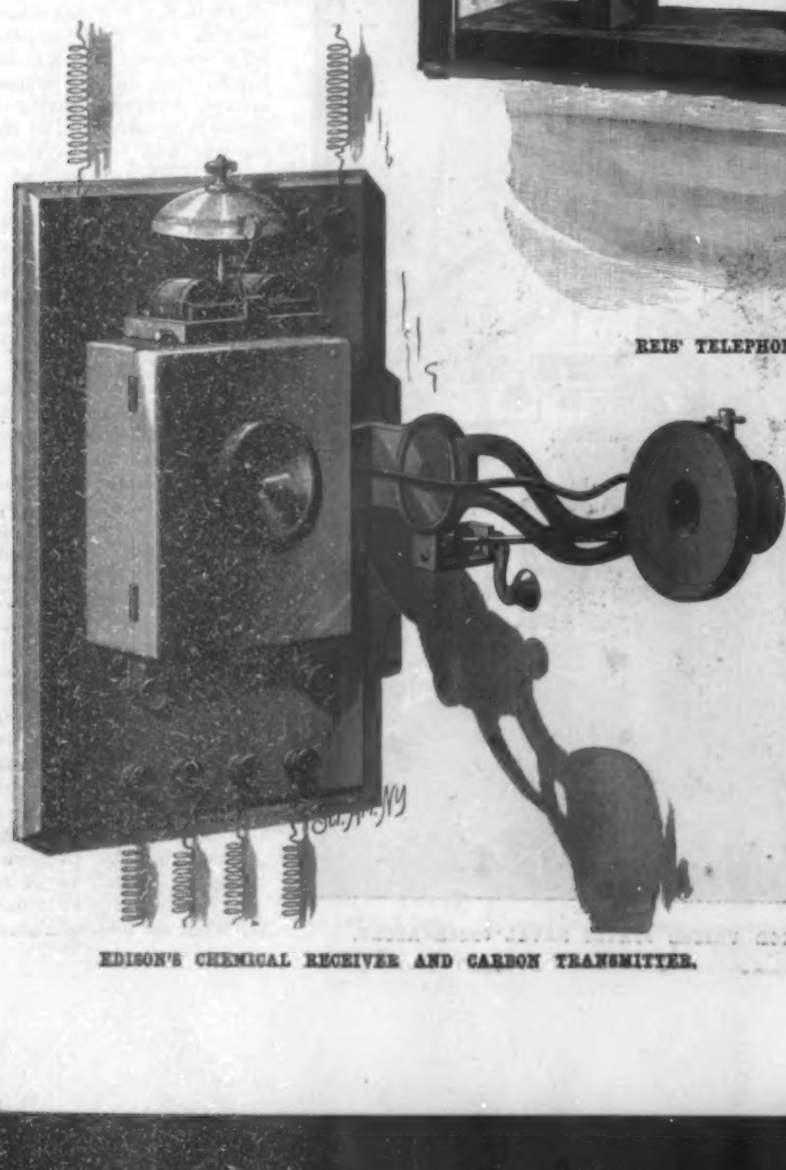
In 1856, Du Moncel had discovered that when two conductors are in contact the electrical conductivity of their contact varies with the change of pressure therein. The Bell telephone, in which the gold beater's skin for a diaphragm was early abandoned, and a plate of iron substituted therefor, was astonishingly sensitive to minute variations in sound when used as a receiver; when used as a transmitter, the agitation of the plate by the voice produced such minute changes that the system embracing a Bell telephone at each end was very imperfect and was regarded as not much better than a scientific curiosity. The Du Moncel principle was now applied to telephony, Edison and Hughes being among the earliest experimenters. The telephone system took a new shape. A transmitter based upon the use of a carbon contact was used. The receiver was a Bell telephone. As a carbon contact, however, much agitated, generated no current, a battery was also put into the circuit and at once the telephone system was completed; talking in an ordinary tone of voice into the microphone, the telephone miles distant repeated the sound. The rest was detail. The most extraordinary results were produced by some of the early transmitters. Edison adopted a carbon button which was held against a contact piece by a diaphragm. This proved astonishingly sensitive to the voice. It was only one of a whole series of changes which were rung upon the microphone. Carbon balls, powder, and rods in every conceivable relation were adopted. The microphone made the telephone a success.

It was rapidly introduced in commerce. One of the curiosities of the telephone was Edison's loud-speaking



REIS' TELEPHONE RECEIVER.

REIS' TELEPHONE TRANSMITTER.



EDISON'S CHEMICAL RECEIVER AND CARBON TRANSMITTER.

chemical telephone. This receiver was based on a chemical principle. Directly back of a micro-diaphragm was a cylinder of plaster of Paris moistened with a chemical solution. A strip of platinum bore, spring cushion, against the surface of the cylinder, the other end being attached firmly to the center of the diaphragm. The instrument was placed in a circuit, one wire connecting with the spring and the other with the cylinder. When the cylinder was turned, it pulled upon the diaphragm evenly and no sound was produced. If a current from the transmitter were passing, its action on the chemical solution caused the mechanical resistance or the friction between the cylinder and the spring to vary, and thereby the diaphragm was vibrated in exact accordance with the original motions of the diaphragm of the transmitter. In this way the message was very loud and could be heard over the whole room. The telephone at once went into extensive use and was introduced everywhere. Enormously expensive law suits were instituted to determine the proprietorship in the basic inventions, which were decided in favor of the owners of the Bell patent, who have succeeded in maintaining a monopoly of the business for many years.

As now used, the telephone operating with a microphone transmitter and a Bell telephone receiver uses the secondary or induced current. To put subscribers in communication with each other what are known as switch boards are operated in the central exchanges. Some of these switch boards are enormous pieces of work representing thousands of dollars in value and embodying in their construction hundreds of miles of wire. Gradually the instruments have taken a single type of construction and the telephone industry has become one of the greatest electrical interests of the day. By the use of more perfect instruments and heavy copper wire the area covered by the telephone has been greatly extended and long distance lines have been established between the leading cities of the world.

STATISTICS OF THE TELEPHONE BUSINESS OF THE UNITED STATES FOR 1895.

Number of exchanges	927
" " branch offices	686
" " instruments in hands of subscribers	674,976
Miles of wire on poles	290,324
" " " buildings	12,861
" " " underground	184,515
" " " submarine	172
Total employes	11,980
Total stations	281,695
Estimated daily exchange connections	2,851,420
Average cost of connection to the subscriber, from 1 cent to $10\frac{3}{5}$ cents.	
Miles of underground wire in New York	28,986
" " " " " Chicago	20,252
" " " " " Boston	15,687
" " " " " Philadelphia	10,990

FIFTY YEARS OF THE SCIENTIFIC AMERICAN.

The present issue is published in the form of an historical review of the progress of science and mechanical industries during the past fifty years, and as it is commemorative of the fiftieth anniversary of the publication of the SCIENTIFIC AMERICAN by the present owners, it will, we feel sure, not be considered amiss if we give some account of the early beginnings and struggles through which the journal passed before it had made for itself a position of authority in the particular field to which it is devoted. The early numbers of the paper are rarely attainable, and cannot generally be reached even in our large public libraries. We have reproduced some pages of the first issues, in order to give our readers some idea of the character of the paper at its inception, and we give below some account of its peculiarities and characteristics.

The size of the paper was more like that of the present daily newspaper. It had four pages. All the matter was printed on both sides of one large sheet and folded in the center so as to make a folio $19 \times 13\frac{1}{2}$ inches.

Across the engraved heading, on which were shown steamboats, waterfalls, windmills, factories and a temple, as may be seen by examining the facsimiles of these early issues published on the front page, was printed the name, "SCIENTIFIC AMERICAN," in large letters.

PATENT DEPARTMENT OF MUNN & COMPANY, 1849.

From a contemporary print.

To those interested in studying the progress of science in this country, the first volume is instructive in showing the gradual, yet rapid development that has taken place. The proprietor, then, Mr. Rufus Porter, was a versatile genius. Finding the world of science too small, he branched out in several directions; included poetry, temperance and religion among the subjects for discussions and essays. Temperance combined with science was uppermost in his mind, and gave the journal a high moral tone.

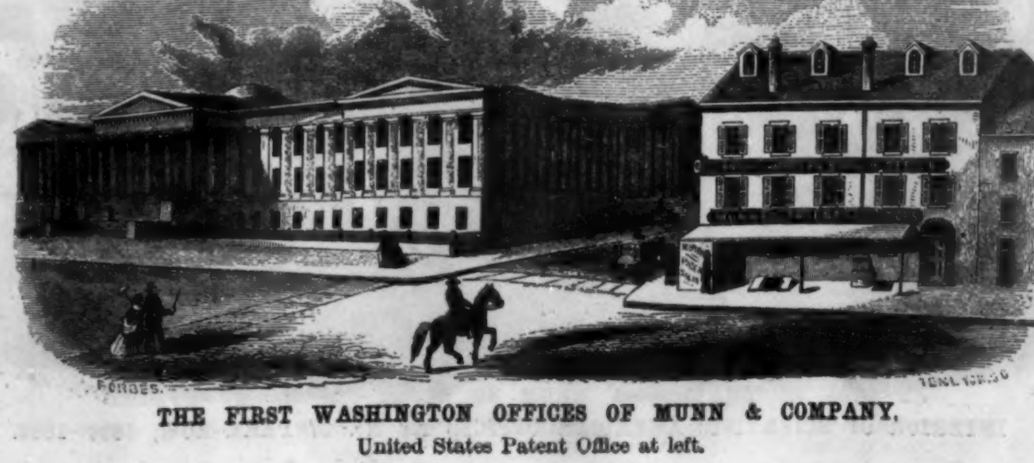
An examination of the business columns of the new paper will reveal many curious advertisements, and in them will be found some names well known to-day. There appears the advertisement of Daniel Davis' journal "Electrical Apparatus," a review of his famous book, "Manual of Magnetism," ranking as the modern "Gilbertus de Magnete." Adams & Company's Express advertise largely, stating that it sends daily iron chests to Pittsburg for the transportation of valuables. "The Pioneer and Express Line" takes goods to Philadelphia in three and a half days, in perfect order. Advertisements of daguerreotypes and supplies show the extent and interest in the new art, at that time, of photography. Another interesting advertisement is that announcing the Eighteenth Annual Fair of the American Institute, at Niblo's Garden, October 6, 1845, with its cattle show out of town on the present site of the Fifth Avenue Hotel, opposite to what is now Madison Square Park. In the issue of October 9 is a short description of the fair. Among the 1,300 entries is Hoe's printing press, Colt's repeating pistol, and Gurney's daguerreotypes, all of them time honored.

It was quite difficult to get up good illustrations then. The engravings were crude, yet they enhanced the popularity of the paper in the eyes of subscribers and readers. The illustrations covered several different subjects. On the front page of the second issue is shown a self-regulating windmill; in the next number is a rotary steam engine, and in the succeeding number appears a picture of a traveling balloon, which may be accounted for by the fact that Mr. Rufus Porter was a strong believer in the possibilities of aerial navigation. In later issues may be found as front page embellishments illustrations of a semaphoric telegraph, a steam carriage for common roads, Brown's dovetailing machine, a combination trunk lock, and an improved tubular boiler.

On October 20, 1845, the office was destroyed by fire, which caused an omission of two issues of the publication. In the November 13 issue, the first published after the fire, is a very characteristic editorial giving interesting details. The loss is placed at seven hundred dollars; not insured. In the same number as many as eight vessels are spoken of as being engaged in commerce on Lake Superior, while more vessels are building. It also mentions that a line of telegraph is being laid from New York to Pittsburg and that one between New York, Philadelphia and Baltimore will soon be completed.

Another item describes the steamship Great Britain, one of the earliest screw vessels, and attacks the practicability of screw propulsion. Railroad progress is given a prominent place. One item tells its own story: "Norris, of Philadelphia, has sent two more of his splendid locomotives to Russia." It demonstrates at how early a date the American locomotive was appreciated abroad, and is prophetic as regards the adoption of American machinery by Russia. It has been recently stated that an immense locomotive plant will be established in Russia, based on American ideas, as carried out by the Baldwin Locomotive Works, of Philadelphia, for the equipment of the great Siberian Trans-Continental Railway, which was at that time projected, but which is not yet completed. Another item alludes to a great work that is being done in the grading of thirty miles of roadbed, expecting it would be completed during the winter. The Baltimore and Ohio road has 177 miles finished. Most extraordinary of all, in the issue of December 11, 1845, is found the statement that "the last project we have heard on this subject is that for the construction of railroads elevated on rows of permanent columns to be erected in the principal streets of this city. We believe this project to be not the most visionary, however, and shall probably give an illustration in a future number." Quite a remarkable suggestion in view of the fact that it was not actually carried out until twenty or more years later, and may be said to be the foreshadowing of our present elevated railroad system.

Captain Eads' proposed ship railroad, across the Isthmus of Panama, attracted considerable attention, because of the ingenious application of hydraulic power to sustaining the strains on ships. But in the first volume of the SCIENTIFIC AMERICAN is to be found a ship railroad which solves the problem at once. It is proposed to mount a great tank upon wheels, to float the ships into it, then to close its ends like a lock, and carry the whole across the land,



THE FIRST WASHINGTON OFFICES OF MUNN & COMPANY.

United States Patent Office at left.

the vessel quietly floating in the tank or moving lock.

Other features of the paper include a series of articles on the Science of Mechanics, really excellent and worthy of reproduction, on account of the simplicity and aptness of the experimental illustrations. The subject of patents also begins to be noticed, a list of the patents issued in May and June, 1845, occupying less than a column.

However attractive and interesting the early numbers of the SCIENTIFIC AMERICAN may be from a retrospective point of view, it did not possess the elements of success, and, after a brief existence of ten months, Mr. Porter decided to part with all his interest in the paper, and in the early part of July, 1846 (according to the text of the bill of sale), all right, title and interest in the paper, including good will of the business, all types, cuts, engravings, composition cases and the various paraphernalia of a publishing office, including the subscription list, the most important of all, were transferred to the firm of Munn & Company, which was founded for the purpose of acquiring the publication. The value at which the SCIENTIFIC AMERICAN was at that time held, may be judged from the fact that the purchase price was eight hundred dollars. The new firm consisted of Orson D. Munn and his friend and schoolmate, Alfred E. Beach. The latter had been brought up in the office of the New York Sun, of which his father, Moses Y. Beach, was at that time the proprietor, and the young men with the enthusiasm of youth saw a great future, under proper management, for the feeble and struggling little journal. An office was secured in the old Sun building, on the corner of Fulton and Nassau Streets. The knowledge and experience acquired by being in such close relationship with the great daily was of great service to the young publishers. The interior of this office, as it appeared some three or four years later, is shown in one of the cuts reproduced from an early print published at the time. We regret to say we have not been able to procure a picture of the exterior of the Sun building of that day.

The first issue published by Munn & Company made its appearance on July 23, 1846. A facsimile of this number will be found upon the front page of the present issue. It will be seen that Mr. Porter was retained by the young proprietors as editor and for a few months his name still appears in conjunction with theirs upon the title page, but very soon a change is noticeable, and a new spirit is infused into the paper. What was a gain to the general reader at that time is a loss to us to-day, however, for we find the paper begins to lose something of its eccentricities and picturesqueness. It will be observed that articles on the Millerites and the millennium, which was expected in 1846, and in which Mr. Porter was a strong believer, are less frequently noticed in its columns. It will be noticed also that less space is devoted to a discussion of religious problems and temperance. However much the new proprietors believed in the value of these virtues as touching private character, they did not think that a discussion of such problems formed proper subject matter for the columns of a scientific journal. In like manner the Muses began to be neglected, and it will be seen that the department of poetry is gradually curtailed until it finally disappears. The most noticeable change, however, was in the form and size of the paper.

Near the close of the first volume the important announcement is made that it is proposed to enlarge the SCIENTIFIC AMERICAN, to print it from new type on fine paper, and to make it of quarto instead of folio size. Every number is to contain from three to six original engravings of new inventions and a resident correspondent at Washington is to keep the readers informed about what is going on at the Patent Office. Chemistry, architecture, gardening and mechanics are among the subjects promised. It is with regret that we turn away from the first volume, but in opening the second volume, September 26, 1846, we find the promises well fulfilled.

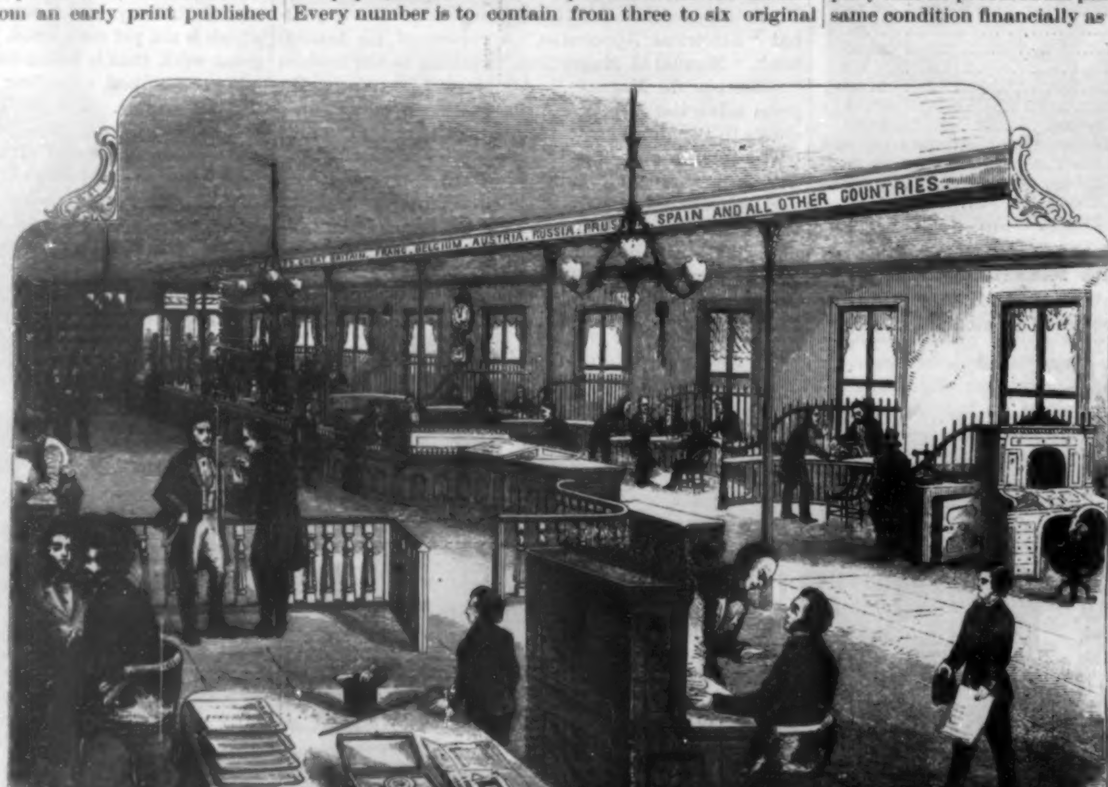
SCIENTIFIC AMERICAN OFFICES, No. 37 PARK ROW, 1859—1882.

In 1847 the Mechanics' Journal, published at Albany, by Joel Munsell, was purchased, and its editor, Mr. Robert McFarlane, succeeded Mr. Porter as editor of the SCIENTIFIC AMERICAN.

In 1849 Mr. Salem H. Wales, now one of the commissioners of the new East River bridge, purchased an interest in the SCIENTIFIC AMERICAN, and was very actively interested in the editorial department till 1871, when he retired from the firm and became actively engaged in politics. Soon after this he was nominated by the Republican party for Mayor of New York City, but was defeated at the polls by the Democratic nominee.

The changes gradually introduced in the paper began to produce the anticipated results, and the journal slowly but surely increased in influence and circulation. The young proprietors were at this early date brought into contact with inventors, some of whom were successful, the great majority of whom were struggling. A Mr. Elias Howe was one of the latter, who frequently called with reference to a wonderful machine of his which would sew by simply turning a crank. His name was soon destined to be known all over this continent and all through Europe as well. Needy and discouraged like the typical inventor, he could not find anyone who was willing to risk his capital in this curious machine. A. B. Wilson, the inventor of the Wheeler & Wilson sewing machine, was also a frequent caller at the office, and it was through the agency of Munn & Company that he procured his patents. He was much in the same condition financially as the great Howe. He was fortunate in associating himself at an early date, however, with a man of means, great foresight and good judgment, Mr. Nathaniel Wheeler. The great Wheeler & Wilson establishment was the result of the uniting of their talents. Mr. Munn and Mr. Beach were in this way at an early date brought into contact with the inventors of the country, and they decided to establish a patent department in connection with the publication of the SCIENTIFIC AMERICAN, which had now been in existence several years, and which was this time a successful and influential paper.

This announcement had hardly been made before the office was besieged with inventors, who engaged Munn & Company to prepare their specifications and drawings and attend to their interests before the Patent Office at Wash-



INTERIOR OF SCIENTIFIC AMERICAN OFFICES AT No. 37 PARK ROW, 1859—1882.

in n. Affairs now moved rapidly and it w found necessary to establish a branch off at Washington. A view of these first off as they appeared at that time has been rep luced from a print of early date. These off were opposite the Patent Office.

J ge Mason, when he retired as Commi ner of Patents, became associated with Mu & Company in their patent departme He was an able man, very popular wit inventors, and was most successful in figh g to a successful issue the extension of t Morse telegraph patent. This noted inve tor was at this time a constant visitor at t office of the SCIENTIFIC AMERICAN, in co sultation with Judge Mason.

Cap ain John Ericsson Commodore Edwin A. Ste ens, and Captain James B. Eads were amon the other celebrities of those days who were constant visitors at the office.

In 1859 the offices in the old Sun building were found to be too contracted, and new quarters were secured at 37 Park Row (now the Potter building), opposite the City Hall and the New York Post Office. These offices were in a central and convenient location and were large and commodious, and admirably adapted to the work of the office. Several views of the exterior and interior are shown reproduced from contemporary prints.

MODEL ROOM AT No. 37 PARK ROW.

On January 31, 1882, the Park Row office was destroyed by fire, the second conflagration the business had to pass through. The old building was a great center for patent lawyers, and a large quantity of irreplaceable models and valuable papers were destroyed. Temporary quarters at 261 Broadway, corner of Warren Street, were secured on the same day and were opened for business the next morning. In the fire was destroyed the type plant used for printing the subscription lists. To avoid writing wrappers and not delay the issue of the paper, photographic copies of the subscription lists that had been saved were made, and these photographic prints were attached to the regular wrappers in the usual way—an illustration of the utility of the science of photography in an emergency.

The temporary quarters being too contracted for the business, the present commodious and well lighted offices at 361 Broadway, corner of Franklin Street, were secured, where two spacious floors are required to accommodate this large business. The engravings published on another page show the various departments of the patent business.

It was decided at the time of the Centennial Exposition in 1876 to publish a supplementary weekly paper, which could be devoted to the many objects of interest shown at the exhibition, and in which articles relating to the progress of the arts and sciences in foreign countries could be published, as well as abstracts of lectures and papers read before the various scientific and technical societies at home and abroad. This publication is known as the SCIENTIFIC AMERICAN SUPPLEMENT. No further mention of this journal is necessary, as this paper is well known to our readers. About the same time the Export Edition of the SCIENTIFIC AMERICAN made its appearance for circulation abroad. It was practically a monthly reissue of the SCIENTIFIC AMERICAN. During the past few years the trade relations between the United States and the South American republics, Cuba and Mexico, had become so extensive that it was decided to publish an edition of the SCIENTIFIC AMERICAN in Spanish. This journal is extensively read in all the Spanish-speaking countries. In 1885 the Building Edition of the SCIENTIFIC AMERICAN was established, and it at once met with public favor, and has acquired a very large circulation. It is a monthly publication and is well known to most of our readers, so it needs no comment here.

The copartnership which had lasted so many years was terminated by the sudden death of Mr. Beach, on January 1 of this year, thus rendering necessary the conversion of the business into a corporation under the laws of the State of New York.

The following sonnet in honor of the golden anniversary of the SCIENTIFIC AMERICAN was contributed by Mr. George A. Avery, one of our oldest employés:

TO THE SCIENTIFIC AMERICAN.

A laurel garland through thy name we string,
Since half a century thy work hath grown;
For at thy birth-time arts were little known,
And sciences were meagre chronicling,
Till great invention gave us everything
Which fosters thrift or soothes the sufferer's moan.
Those fifty years are long, Thou art alone
In lapse of years and glories time doth bring.

And still the senior of the youthful twain
That started thee aright in thought and deed
Directs the lamps of knowledge, truth and peace
Upon thy columns with a loving pain
For him who died o'er conscious of thy need
Of the life work he gave for thy increase.

THIRTY YEARS AGO—STAFF OF MUNN & COMPANY IN 1866.

Group designed by Gustav Dieterich, one of the draughtsmen at that time.

PRESENT OFFICES OF THE SCIENTIFIC AMERICAN.

FEED THE LAWN AND YOU CAN ALMOST See the Grass Grow

Lyon's Automatic Fertilizing Lawn Feeder (ODORLESS)

is a neat, light, little device, attached between the end of the hose and the nozzle, which automatically dissolves a stick of

LYON'S CONCENTRATED LAWN FOOD,

diffusing it through as much water as will pass through an ordinary garden hose in about one hour. It is clean, odorless, non-poisonous, and will give perceptible results after one week's use on your lawn. It produces a dark-green foliage and a healthy growth.

From the July issue of AMERICAN HOMES, Knoxville, Tenn.

None but those who have had the experience know how difficult it is not only to bring the lawn up to a condition of uniform vigor but to keep it there as well.

Nothing adds more to the beauty of a home than a rich greensward on the lawn, but if marred by bare or scant places and alternate luxuriant tufts, the evidence is painfully apparent that something is lacking, and the owner is apt to feel a guilty knowledge of lack of proper nutrition or care, no matter how earnestly he has sought for a remedy for the scrawny appearance.

If but a small "patch" of grass can be obtained, let it have the thrifty, well-cared-for look which commends it to all, and shows the care and intelligence of the occupant of the premises.

It is not every one who can tell just what to do and when to do it, which will make and keep the lawn in apple-pie order, and many who have striven hard for the desired results have ended in failure and disappointment.

To such, Lyon's Automatic Fertilizing Lawn Feeder comes as a boon. Its use is so simple, and the good results so positive that it is like many another valuable invention, one wonders why it was not thought of long ago. If this is used with regularity, the changed appearance of the lawn will be marvelous, and it will only remain for the lawn mower to do its duty, to produce that even, velvety appearance so universally written about and so seldom seen.

The editor of AMERICAN HOMES has given this Fertilizer a test and is convinced that its purchase will prove one of the best investments a home-owner can make.

For sale at Seed and Hardware Stores, and by dealers generally, or a complete outfit, consisting of one holder and twelve sticks of the food, prepaid to any address on receipt of **$1.00**.

We want a bright man in every city in the United States containing a system of water works to do special work for us. Pleasant work, splendid pay. Small capital required. Apply at once.

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2	Esther Waters. George Moore.	336
3	The Man in Black. Stanley J. Weyman.	128
4	Dodo. E. F. Benson.	224
5	Ships that Pass in the Night. B. Harraden.	176
6	A Rogue's Life. Wilkie Collins.	192
7	The Duchess. "The Duchess."	224
8	Called Back. Hugh Conway.	160
9	A Wicked Girl. Mary Cecil Hay.	176
11	Wedded and Parted. Charlotte M. Braeme.	112
12	The Bag of Diamonds. George Manville Fenn.	176
13	The Octoroon. Miss M. E. Braddon.	160
14	A Study in Scarlet. A. Conan Doyle.	176
15	Forging the Fetters. Mrs. Alexander.	160
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29	The House of the Wolf. S. J. Weyman.	192
30	The Earl's Error. Charlotte M. Braeme.	160
40	A Golden Heart. Charlotte M. Braeme.	192
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42	The Idle Thoughts of an Idle Fellow. Jerome.	112
43	In Durance Vile. "The Duchess."	112
44	A Little Rebel. "The Duchess."	128
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48	A Marriage at Sea. W. Clark Russell.	176
50	The Other Man's Wife. John Strange Winter.	192
51	On Her Wedding Morn. Charlotte M. Braeme.	192
52	Stage-Land. Jerome K. Jerome.	112
53	At the Green Dragon. B. Harraden.	160
[illegible]	Singularly Deluded. Sarah Grand.	128
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62	The Tour of the World in Eighty Days. Verne.	192
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77	Afternoon, and other Sketches. "Ouida."	128

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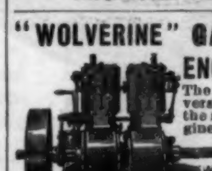

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A HALF CENTURY OF MINING.

Some fifty years ago one James Wilson Marshall, a carpenter, was at work deepening the tail race of Sutter's mill, in El Dorado County, California, when he noticed the glitter of gold in the gravel which he had thrown up in his excavation of the night before. That was on the morning of January 19, 1848. When Marshall picked up the yellow fragments, he little dreamed that he was holding in his hand the key to one of the richest natural treasure vaults that has yet unlocked its wealth for the enriching of a nation.

At the time of the discovery of gold in California the mineral industry of the United States was in its very infancy, as may be judged from the fact that the annual output of coal, which in 1895 reached the enormous total of 196,442,451 tons, in 1848 amounted only to 5,000,000 tons, and that the total output of pig iron was but a quarter of a million tons, as against nine and a half million tons in 1895. Lead was mined to the modest extent of 10,000 tons, and it was but two years previous to the discovery of gold, or in 1846, that copper mining had its small beginning with a total output of 150 tons.

The effect of the Sutter's mill discovery was simply magical. Its announcement was received with unbounded enthusiasm, and it drew a vast and motley army of adventurers to the Pacific coast in search of the precious metal. When we consider how crude were the methods of recovery, the yield of gold was truly phenomenal. In the first year about $10,000,000 worth was taken out; this rose to $40,000,000 in 1849; $50,000,000 in 1850; $55,000,000 in 1851; $60,000,000 in 1852; and it reached its highest point in 1853, when a total value of $65,000,000 was recovered.

During these first six years the methods of extracting the gold were very crude, and therefore very wasteful. The mining was carried on in what were known as placer deposits and the favorite apparatus of the "forty-niner" consisted of the pan, the rocker, the Long Tom and the sluice box.

In the course of time, as the rich alluvial deposits became worked out, the miner turned his attention to the gold-bearing rock, and the recovery of the gold became a more difficult and costly matter. There was a call for science, skill, and capital, and the gold mining industry passed into the hands of the engineer and the capitalist. The pan, the rocker, and the sluice gave place to the highly organized stamp mill, with its costly plant consisting of stamp batteries, amalgamating pans and concentrating tables. Chemistry was called in to determine the composition of the various ores, and the expert metallurgist became an indispensable member of the staff of the mine. In due time the rebellious ores came to be treated by roasting, and last, and most brilliant feat of all, was the introduction of the various leaching processes, by which in some cases practically the last trace of the gold has been recovered from the tailings.

Mention should also be made of the remarkable development of hydraulic mining, whereby enormous deposits of gravel, which contain only a few cents' worth of gold to the cubic yard, can be worked at a profit. As its name indicates, the mining is done by the action of water, which is discharged under enormous pressure against the wall of gravel and bowlders, tearing it down and thoroughly segregating the material which is then carried through sluices, where the gold is deposited.

It was natural that, in the first rush for gold, the less valuable metal, silver, should have received but little attention. There were about two and a half million ounces of gold taken out in 1850, whereas the total output of silver for that year was only between thirty-eight and thirty-nine thousand ounces. It rose to 12,375,-360 ounces in 1870, and reached the maximum in 1890, when it amounted to 54,517,440 ounces. Last year there was a decline of about eight million ounces, the total being 46,331,205 ounces.

There is no country in the world where the mining and metallurgy of gold and silver has been subjected to such searching and successful experimental work as in the United States. To have graduated from an American School of Mines, and to have gained his experience in the practical routine of Americal mining, opens up the way to responsible and highly lucrative positions in any of the great mining centers of the world.

The development of copper mining in the United States has been no less remarkable than that of gold. It had its commencement a year or two previous to the discovery of gold, and the progress of this industry, especially in the last decade and a half, has been without a parallel. From a small beginning of 150 tons in 1848 the output grew steadily to 27,000 tons in 1880, when it began to increase at an astonishing rate, reaching a total of 119,000 tons in 1890, and 172,522 tons in 1895—an amount which is greater than the total production of all the other countries of the world combined. This rapid increase in production has taken place in spite of the fact that the market price of copper has been steadily declining. Although it is worth to-day only one-half what it was twenty-five years ago, the output is over thirteen times as great, and the copper mines of Michigan and Montana are reckoned as among the best paying investments of the day.

This success has been achieved by the introduction of improved machinery, and by the administration of the mines with a strict regard to economy of labor. Some idea of what skillful engineering, combined with well directed economy, can do may be gathered from the fact that the great Calumet and Hecla mine in Michigan is paying a yearly dividend of 150 per cent on a paid-up capital of $1,250,000, and this, although the value of copper has decreased 50 per cent in the past twenty-five years. The above figures are a tribute to machinery and good management, which, in the last twenty years, have reduced the cost of labor in getting out the ore more than 400 per cent.

TOTAL OUTPUT OF LEADING MINERALS IN THE UNITED STATES, 1895.

		Value.
Pig iron, long tons	9,446,308	$105,688,543
Gold, ounces	2,265,612	46,830,200
Copper, pounds	386,473,650	38,944,988
Silver, ounces	46,331,205	30,254,926
Lead, short tons	156,854	10,132,768
Zinc short tons	81,878	5,942,890
Quicksilver, flasks	38,978	1,313,580
Aluminum, pounds	900,000	495,000
Antimony, short tons	433	68,847
Bituminous coal, short tons	138,079,466	125,430,488
Anthracite coal, short tons	58,362,985	80,948,608
Crude petroleum, barrels, 42 gallons	50,652,085	42,547,701
Building stone	...	32,000,000
Lime, barrels, 200 pounds	60,000,000	30,000,000
Iron ore, long tons	16,950,000	29,662,500
Coke, short tons	9,927,348	15,256,985
Natural gas	....	12,000,000
White lead paint, short tons	92,000	8,740,000
Salt, barrels, 280 pounds	12,921,498	5,944,348
Hydraulic cement, barrels, 300 pounds	7,694,053	4,697,295
Clay, refractory, short tons	3,750,000	4,500,000
Marble, cubic feet	6,942,533	4,086,261
Phosphate rock, long tons	831,496	2,577,643
Alum, short tons	75,000	2,225,000
Roofing slate, squares	645,361	2,082,229
Portland cement, barrels, 400 pounds	749,060	1,430,069
Value of total mineral output		$672,881,505

More extensive, and bringing even a greater increment of wealth to the nation than the production of gold, silver, and copper combined, has been the development of our vast natural resources of coal and iron.

We have shown that the past half century practically includes the history of the development of coal and iron mining on a scale of any magnitude. Five million tons of coal and less than half a million tons of pig iron will cover the output in 1846; and although the earliest records of the iron industry take us back to the early years of the seventeenth century, when iron ore was shipped from Virginia to England, the commencement of the era of its modern growth may justly be assigned to the decade 1840 to 1850. This period saw the rapid development of the two great means of transportation—the locomotive and the steamship—whose manufacture and propulsion created an immediate and growing demand for iron and coal. Increased facilities of transportation extended the market for manufactured articles; and, as the factories multiplied, the demand for iron machinery and coal fuel increased rapidly. The industrial development of the country thus necessarily involved a corresponding increase in the output of coal and iron; and the story of our commercial prosperity is faithfully chronicled in the tables of our production of these minerals. This has risen in 50 years from 5,000,-000 tons of coal to 196,442,451 tons; and from 500,000 tons of iron to 9,446,300 tons in 1895.

The European mine owner is puzzled to understand how we can sell our coal for 30 to 40 per cent less per ton than he can afford to do, when we are paying the miner over twice as high a wage.

The answer is simple, and with it we will close this brief review: Better paid labor produces a more intelligent workman and a larger output of work; it stimulates the introduction of labor-saving machinery, and renders economy of administration an imperative necessity.

GREAT SEAL FORMERLY ISSUED WITH BRITISH PATENTS.

THE GREAT SEAL ON BRITISH PATENTS.

The letters patent formerly issued by the British government were very formidable affairs, and in the accompanying illustrations we publish a reproduction of the great seal which was affixed to each document. The patent itself was a large folio in size and printed only on one side upon heavy parchment. The seal was affixed by means of a red cord to the lower border. This was a very beautiful affair, and measured 6½ inches in diameter. On one side of the seal is a representation of Queen Victoria in coronation robes, supported on either side by female figures, presumably Justice and Science. On the obverse side her Majesty appears mounted on a charger led by an esquire, who casts his eyes over his shoulder at his royal mistress.

The joy and pride of the inventor upon receiving this imposing document must have been very great. The seal usually was protected by a tin box, which, together with the patent papers, were inclosed in an outer case of leather, the whole weighing about four pounds. The practice of affixing the seal to patents continued until 1877, when the old act was repealed. The government fees alone, at this time, were £25—$125. These fees remained in force until 1883, when the act was again amended. Although the old seal added dignity to the papers, the public parted with it without regret, and the paper seal used now on British patents is found to be cheaper, more durable and less likely to get out of order.

CONTENTS.

(Illustrated articles are marked with an asterisk.)

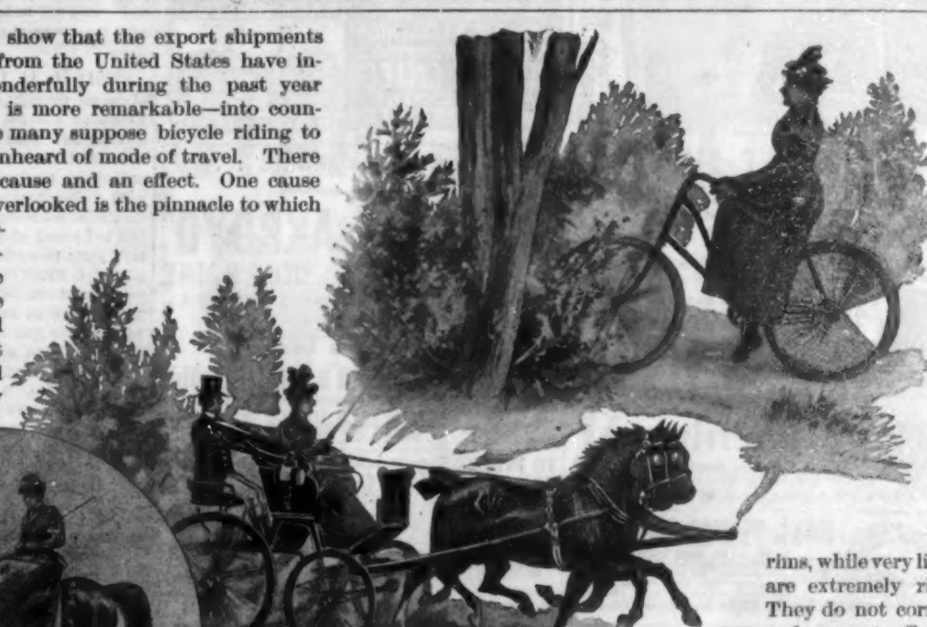
UNIT TRANSPORTATION REVOLUTIONIZED.

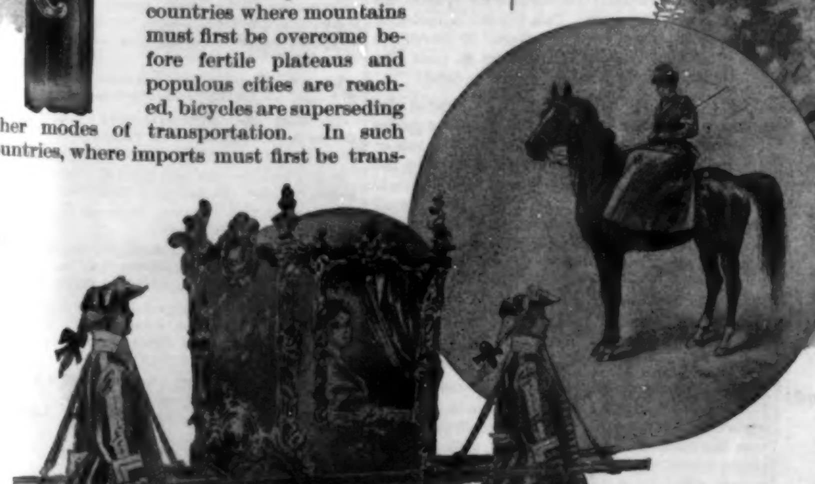
Taking it the world over, there is no doubt but that the present is the age of the bicycle. The number now in daily use is legion. Yet we are confident that this increase in their use is but the beginning; the first awaking into a realization of the part the modern bicycle will yet play in the history of the world.

The growth of cities can even now be partially accounted for by the vast increase in the use of cycles from a utilitarian point of view—why not, then, the future growth of empires?

Even at the present time, in foreign countries where mountains must first be overcome before fertile plateaus and populous cities are reached, bicycles are superseding other modes of transportation. In such countries, where imports must first be transported in small cases on mule back, bicycles with wheels and fittings removed are easily and cheaply transferred. In some countries where machinery is unobtainable and it is impossible to make roads of sufficient width for carriages, paths suitable for bicycle riding are being constructed with comparative ease.

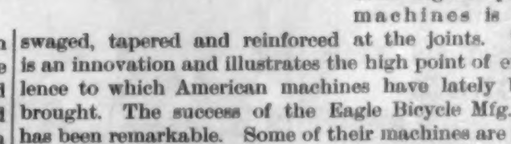
Statistics show that the export shipments of bicycles from the United States have increased wonderfully during the past year and—what is more remarkable—into countries, where many suppose bicycle riding to be yet an unheard of mode of travel. There is always a cause and an effect. One cause not to be overlooked is the pinnacle to which a few American makers have raised the quality and consequent speed and durability of their cycles. Certain American bicycles are now in greater demand in foreign countries and even in England than home productions.





One of the most novel, yet popular and satisfactory machines, is manufactured by the Eagle Bicycle Mfg. Co., Torrington, Conn., U. S. A. While in the main their machines are similar in outline to other standard bicycles, extreme fineness in detail construction is noticeable; and, furthermore, Eagle Bicycles may be obtained, when ordered, fitted with their patented Aluminum Rims. These rims are especially adapted for inner tube tires which are easily detached and repaired. The rims, while very light, are extremely rigid. They do not corrode and are not affected either by moisture or heat.

All tubing used in the construction of their highest priced machines is cold swaged, tapered and reinforced at the joints. This is an innovation and illustrates the high point of excellence to which American machines have lately been brought. The success of the Eagle Bicycle Mfg. Co. has been remarkable. Some of their machines are now being used by the mounted police of New York, and shipments of Eagle Bicycles with Aluminum Rims and Cold Swaged Frames are being made to all parts of the world. Their immense factory at Torrington, Conn., devoted exclusively to the manufacture of high grade bicycles, is wonderful, in view of its special adaptation to the purpose, and the costly machinery employed.—Adv.



Notes & Queries

HINTS TO CORRESPONDENTS.

Names and Address must accompany all letters or no attention will be paid thereto. This is for our information and not for publication.

References to former articles or answers should give date of paper and page or number of question.

Inquiries not answered in reasonable time should be repeated; correspondents will bear in mind that some answers require not a little research, and, though we endeavor to reply to all either by letter or in this department, each must take his turn.

Buyers wishing to purchase any article not advertised in our columns will be furnished with addresses of houses manufacturing or carrying the same.

Special Written Information on matters of personal rather than general interest cannot be expected without remuneration.

Scientific American Supplements referred to may be had at the office. Price 10 cents each.

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Minerals sent for examination should be distinctly marked or labeled.

(6899) **H. H. B. asks:** 1. How many feet of No. 30 German silver resistance wire would it take to reduce a current of 20 cells Mesco dry battery (in series—about 6 amperes with a potential of about 30 volts) to $\frac{1}{1000}$ of an ampere, and about what would it cost? A. Approximately, 220,000 feet. You would do much better if you would employ some other type of resistance, or if you would use finer wire. Thus one fourth of the above length of No. 36 wire would answer. 2. What is the best mixture with which to launder collars and cuffs and shirts? A. It is more a matter of manipulation than of starch. You may add a little paraffine wax. A sad iron with an irregularly roughened surface is used. 3. What would be a good colorless enamel or lacquer? A. Celluloid varnish is probably the best colorless lacquer, although white shellac answers very well. The formula for colorless lacquer would depend upon the metal, etc., to which it is to be applied; no general formula. 4. How can we get rid of those small red spiders that stay in the woodwork of a house? A. Try using borax around the cracks; it is doubtful if anything will be very efficacious. 5. How must I charge the induction coil described in "Experimental Science" to get a 5 inch spark? A. Make it twice as large in its lineal dimensions, and wind secondary in six or more sections.

(6900) **G. C. W. writes:** I have 25 cells of storage battery which I wish to charge and use about 10 hours a day. I also have a 110 volt direct current line at my disposal. Is it the best to connect the cells all in series, and then in series with a 110 volt lamp, and let it charge while using, or would it be better to put a 50 volt lamp in series? The reason I wish to use the storage battery is to get a steady current; the charging current varies at times. If neither of the ways is correct, please advise what is best. A. The lamp will cut down your current a good deal, leaving you about half of an ampere of charging current when connected with the battery. This will make the charging very slow. Otherwise the arrangement will work. Always charge in series.

(6901) **H. B. L. says:** Will you kindly advise me through the columns of the SCIENTIFIC AMERICAN as to the best paste to use for attaching paper labels to tin? I am now using a paste, the basis of which is dextrine, but it leaves the edges sticky, and a preliminary application of acid is necessary. A. 1. 4 parts shellac, 2 parts borax; water, 30 parts; boil until the shellac is dissolved. 2. Add 4 ounces dammar varnish to 1 pound of tragacanth mucilage. 3. Balsam of fir, 1 part; turpentine, 3 parts; use only for varnished labels. 4. Butter of antimony is good to prepare the tin for the label. 5. Venice turpentine added to good starch paste makes an excellent mounting medium. 6. Use liquid glue or glue dissolved in acetic acid. 7. Add 1 ounce of tartaric acid to each pound of flour used in making flour paste. 8. Add 10 per cent flour to tragacanth mucilage. 9. Corrosive sublimate, 125 parts; wheaten flour, 1,000 parts; absinthe, 500 parts; tansy, 500 parts; water, 15,000 parts. This cement is useful for vessels which are kept in a damp place. 10. Starch, 100 parts; strong glue, 50 parts; turpentine, 50 parts; the whole boiled in water. This cement dries quickly.

(6902) **G. J. O. writes:** I would be pleased to have you inform me of the method or process of amalgamating zinc properly. A. If you will rub on mercury with a strip of zinc used as the rubbing tool having scraped your zinc surfaces and dipped them in weak acid, you should have no trouble in uniformly amalgamating them. You may try dipping in an acid solution of mercury, nitrate or chloride (corrosive sublimate), or simply rub the clean zinc wet with acid with a lump of corrosive sublimate. The latter is a most dangerous poison, and rubber gloves should be worn in using it, and if there is any cut on the hand, do not attempt the process described.

(6903) **J. H G. asks** (1) how to make a good cement for hard rubber. A. Dissolve bleached gutta percha in carbon bisulphide. Cement, and when dry brush over carbon bisulphide in which sulphur has been dissolved, or take equal parts of pitch and gutta percha melted together, and linseed oil is added, which contains litharge. Melt until all are well mixed; use no more of the linseed oil than necessary. Apply warm. 2. If the voltage of an induction coil is known, how can the length of spark be found? A. As an approximation allow 10,000 volts to one-tenth inch. 3. How can I make a heavy white smoke which is not poisonous? A. Mix hydrochloric acid vapor with vapor of ammonia, or use steam. The latter, except for its dampness, is the most satisfactory on the large scale.

(6904) **H. S. H. says:** Will you please inform me where I can get information in regard to varnishing maps and drawings or, rather, preparing for varnish? A. Stretch your muslin (ordinary cotton stuff) on a wooden stretcher by means of tacks, cover your map on the back with an even and thin coat of good boiled starch or flour paste or other sticking materials, no matter what, if it only sticks. Lay the map on the cloth, only taking care to do this smoothly and to avoid wrinkles; rub it evenly down after temporarily covering the place you rub with a piece of clean paper, so as to avoid friction over the map itself. Let it dry, and the work is done. In order to avoid wrinkles, it is quite essential to let your paper map, after being covered with the starch paste, soak for a few minutes, so as to give the paper a chance to expand from the moisture. It will then, while contracting from the drying, obtain a very smoothly stretched surface. Bookbinders always carefully observe this when pasting papers on book covers, etc. When dry, size with a weak solution of gelatine and then varnish. A good varnish for paper and maps is made with gum mastic, 6 parts; sandarac, 3 parts; dissolved in a mixture of 3 parts turpentine and 32 parts of alcohol. These ingredients, with the exception of the turpentine, are placed in a tinned copper vessel, in a bath of hot water, and are stirred for several hours until the gums are dissolved; the turpentine is then added and the stirring continued an hour longer, after which strain the varnish and set it aside for use.

(6905) **J. H. G. says:** I wish you would give a receipt through your valuable paper to make an amber oil varnish, same as the best violin makers use. Also how to apply same. A. The true Cremona varnish is of unknown formula; its preparation is a lost art.

Amber, fused	2	oz.
Oil of turpentine	5	"
Drying linseed oil	5	"

The following is for a spirit varnish:

Mastic	1	dr.
Sandarac	1	"
Lac	6¼	"
Alcohol	5	fl. oz.

To tinge with yellow, annatto, aloes, gamboge, or turmeric may be used; for red, dragon's blood or red sanders wood. By mixing the above, intermediate shades may be obtained. The formula is only half the art; much depends on the application, treatment between coats, etc. It should be done by an expert.

(6906) **S. F. says:** Can you give me a table which will show how far a safety bicycle will roll in feet with each revolution of the cranks?

Gear. Inches.	Distance. Ft.		Gear. Inches.	Distance. Ft.	
40	10	47	66	17	27
42	10	99	68	17	80
44	11	51	70	18	32
46	12	04	72	18	84
48	12	56	74	19	37
50	13	09	75	19	63
52	13	61	76	19	89
54	14	13	78	20	42
56	14	66	80	20	94
58	15	18	82	21	46
59	15	44	84	21	99
60	15	70	86	22	51
62	16	23	88	23	03
63	16	44	90	23	56
64	16	75			

(6907) **J. L. Q. says:** Will you kindly inform me how to make and what different articles to use to make carton pierre such as is used in the manufacture of ornaments for picture frames? A. The following is a formula for such a composition: Glue, previously dissolved in water, 13 parts; pulverized litharge, 4 parts; white lead, 8 parts; plaster of Paris, 1 part; very fine sawdust, 10 parts. Oil the moulds in which it is cast to prevent adhesion.

Business and Personal.

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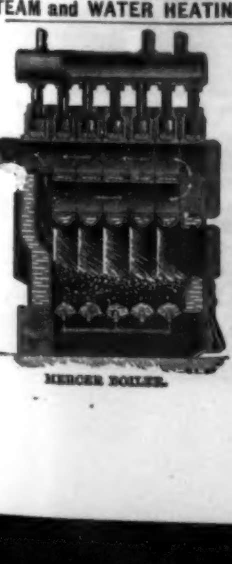

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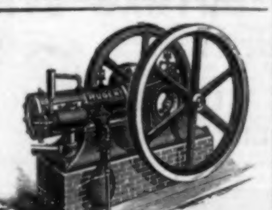

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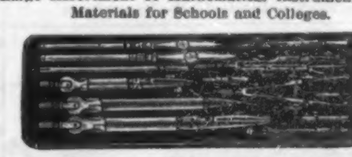

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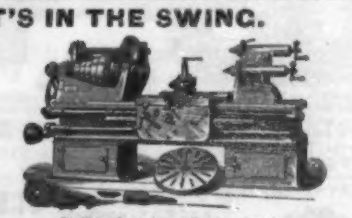

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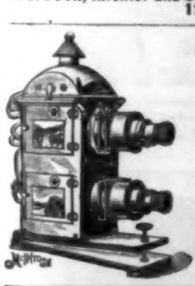

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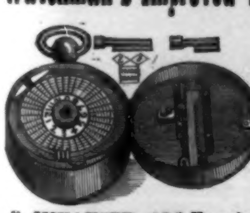

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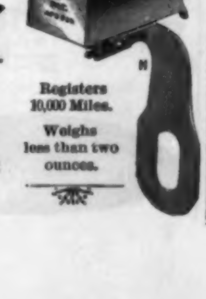

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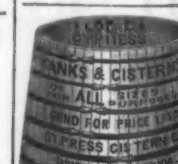

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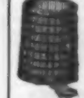

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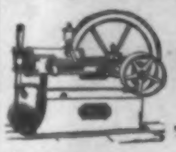
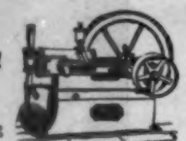

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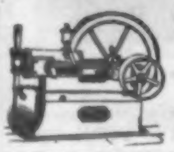
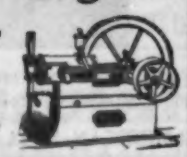

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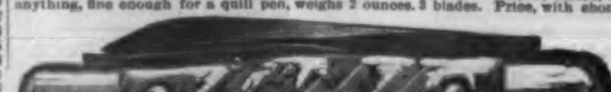

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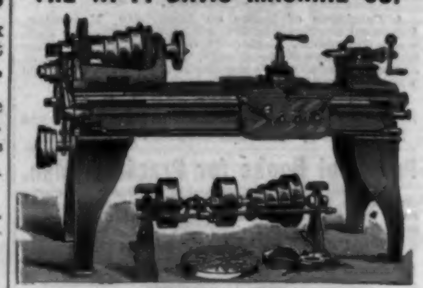

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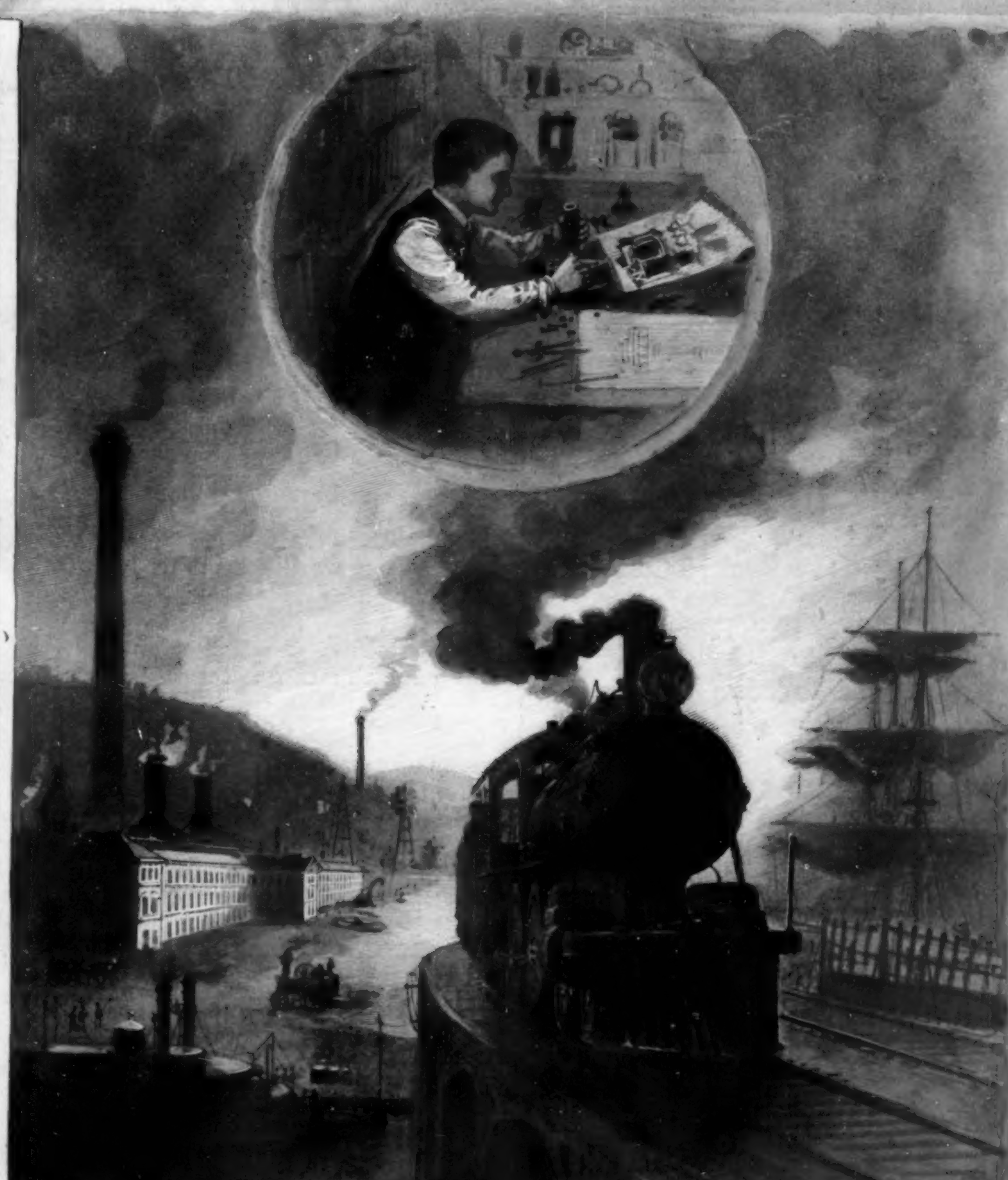

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